IMPACT OF SCHEDULED ATTRITION RATES ON MEETING MONTHLY SORTIE GOALS IN UNITED STATES AIR FORCE BOMB WINGS

A thesis presented to the Faculty of the U.S. Army Command and General Staff College in partial fulfillment of the requirements for the degree

MASTER OF MILITARY ART AND SCIENCE
General Studies

by

CRAIG M. GILES, MAJ, USAF
M.S., Embry-Riddle Aeronautical University, Daytona Beach, FL, 2005

Fort Leavenworth, Kansas
2009

REPORT DOCUMENTATION PAGE			*Form Approved* *OMB No. 0704-0188*
Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing this collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden to Department of Defense, Washington Headquarters Services, Directorate for Information Operations and Reports (0704-0188), 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to any penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number. **PLEASE DO NOT RETURN YOUR FORM TO THE ABOVE ADDRESS.**			
1. REPORT DATE *(DD-MM-YYYY)* 12-06-2009	**2. REPORT TYPE** Master's Thesis		**3. DATES COVERED** *(From - To)* AUG 2008 – JUN 2009
4. TITLE AND SUBTITLE Impact of Scheduled Attrition Rates on Meeting Monthly Sortie Goals in United States Air Force Bomb Wings			**5a. CONTRACT NUMBER**
			5b. GRANT NUMBER
			5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S) GILES, CRAIG M., MAJ			**5d. PROJECT NUMBER**
			5e. TASK NUMBER
			5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) U.S. Army Command and General Staff College ATTN: ATZL-SWD-GD Fort Leavenworth, KS 66027-2301			**8. PERFORMING ORG REPORT NUMBER**
9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)			**10. SPONSOR/MONITOR'S ACRONYM(S)**
			11. SPONSOR/MONITOR'S REPORT NUMBER(S)
12. DISTRIBUTION / AVAILABILITY STATEMENT Approved for Public Release; Distribution is Unlimited			
13. SUPPLEMENTARY NOTES			
14. ABSTRACT During home station training operations, United States Air Force bomb wings use a five-year historical loss rate, also known as attrition, to predict future losses in the monthly flying schedules. The purpose of the attrition is to ensure that units meet their sortie contract consistently. In an era of decreasing force size, it is important for units to maximize aircrew-training operations, without wasting manpower and resources. Thus the primary research question: is the current USAF scheduling technique of using a five-year historical attrition rate an effective way to ensure the bomb wings' consistently meet their monthly sortie contracts? The statistical analysis was convincing that the bomber fleet is more likely to meet the sortie contract in months with high scheduled attrition than in months with low scheduled attrition. Additionally, the research introduced the application of disruption management as a method to manage a flying schedule built with no scheduled attrition to increase the units' efficiency and the schedules' effectiveness. Finally, the research made a recommendation to stop using attrition scheduling in USAF bomb wings, and made two recommendations for future research to identify what capability shortfalls are masked by attrition and to perform similar research on other types of aircraft.			
15. SUBJECT TERMS Aircraft Flight Scheduling, Attrition, Dirsuption Management			

16. SECURITY CLASSIFICATION OF:			**17. LIMITATION OF ABSTRACT**	**18. NUMBER OF PAGES**	**19a. NAME OF RESPONSIBLE PERSON**
a. REPORT	**b. ABSTRACT**	**c. THIS PAGE**			**19b. PHONE NUMBER** *(include area code)*
(U)	(U)	(U)	(U)	90	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std. Z39.18

MASTER OF MILITARY ART AND SCIENCE
THESIS APPROVAL PAGE

Name of Candidate: Maj Craig M. Giles

Thesis Title: Impact of Scheduled Attrition Rates on Meeting Monthly Sortie Goals in United States Air Force Bomb Wings

Approved by:

______________________________________, Thesis Committee Chair
Lowell E. Solien, M.S.

______________________________________, Member
Thomas G. Clark, Ph.D.

______________________________________, Member
David M. Stephan, M.S.

Accepted this 12th day of June 2009 by:

______________________________________, Director, Graduate Degree Programs
Robert F. Baumann, Ph.D.

ABSTRACT

IMPACT OF SCHEDULED ATTRITION RATES ON MEETING MONTHLY SORTIE GOALS IN UNITED STATES AIR FORCE BOMB WINGS, by MAJ Craig M. Giles, 90 pages.

During home station training operations, United States Air Force bomb wings use a five-year historical loss rate, also known as attrition, to predict future losses in the monthly flying schedules. The purpose of the attrition is to ensure that units meet their sortie contract consistently. In an era of decreasing force size, it is important for units to maximize aircrew-training operations, without wasting manpower and resources. Thus the primary research question: is the current USAF scheduling technique of using a five-year historical attrition rate an effective way to ensure the bomb wings' consistently meet their monthly sortie contracts? The statistical analysis was convincing that the bomber fleet is more likely to meet the sortie contract in months with high scheduled attrition than in months with low scheduled attrition. Additionally, the research introduced the application of disruption management as a method to manage a flying schedule built with no scheduled attrition to increase the units' efficiency and the schedules' effectiveness. Finally, the research made a recommendation to stop using attrition scheduling in USAF bomb wings, and made two recommendations for future research to identify what capability shortfalls are masked by attrition and to perform similar research on other types of aircraft.

TABLE OF CONTENTS

ACRONYMS

ACC	Air Combat Command
ACCI	Air Combat Command Instruction
AFI	Air Force Instruction
AFTTP	Air Force Techniques, Tactics, and Procedures
ATC	Air Traffic Control
CAF	Combat Air Forces
CAMS	Core Automated Maintenance System
DY	Dyess AFB, Texas
EL	Ellsworth AFB, South Dakota
EXH	Exercise Cancel, Headquarters
EXL	Exercise Cancel, Local
FHP	Flying Hour Program
HQ	Headquarters
LA	Barksdale AFB, Louisiana
MAJCOM	Major Command
MDSA	Maintenance Data Systems Analysis
MOB	Main Operating Base
MOS	Maintenance Operations Squadron
MT	Minot AFB, North Dakota
P&S	Plans and Scheduling
USAF	United States Air Force
UTE	Utilization
WM	Whiteman AFB, Missouri

ILLUSTRATIONS

TABLES

Page

CHAPTER 1

INTRODUCTION

This study examines the United States Air Force's (USAF) techniques for scheduling and executing monthly flying training schedules in bomber units. Since 2001, USAF active duty end-strength has reduced almost six percent but its deployments have increased by over 30 percent (Howe et al. 2007, 14). This increase in operations tempo combined with a shrinking work force makes it increasingly difficult to plan and execute monthly aircrew training requirements. To meet the monthly aircrew training requirements with work force constraints, the USAF must take full advantage of every scheduled training sortie. This chapter introduces the problem, provides a brief background, statement of the hypotheses and research questions, list of definitions, assumptions, limitations, and concludes by summarizing the significance of the thesis.

Background

Air Force Doctrine Document 2-4, Combat Support, lists "supporting training operations" as one of the peacetime priorities included in readying the force for combat operations (United States Air Force 2005, 15). The most visible form of support personnel conducting training operations are aircraft maintainers generating training sorties for the operations squadron. However, the USAF has not changed its home-station monthly flying scheduling techniques since the Cold War when the USAF had nearly three times its current manning (Correll 1998, 4).

In accordance with Air Combat Command Instruction (ACCI) 21-165, Aircraft Flying and Maintenance Scheduling Procedures, aircraft flying and maintenance

scheduling is a "planned, methodical approach to achieve maintenance and flying goals." Air Force Instruction (AFI) 11-102 best summarized flying goals as the "flying … necessary to train aircrews to safely operate their aircraft and sustain them in numbers sufficient to execute their core tasked mission" (United States Air Force 2002, 4). It is beyond the scope of this thesis to delve into the details for determining how many sorties and flying hours are required to maintain the aircrews' readiness. Instead, this study focuses on the actions taken by maintenance schedulers to meet the aircrews' training requirements.

There are two primary maintenance goals achieved in a successful maintenance and flying schedule. AFI 21-101, Aircraft and Equipment Maintenance Management summarizes these goals as achieving a "balance between sortie production and fleet management" (United States Air Force 2006, 50). Air Force Tactics Techniques and Procedures (AFTTP) 3-21.1, Aircraft Maintenance, expands the concept of balancing sortie production and fleet management by stating:

> The ability to balance fleet health with accomplishing the flying schedule is the most demanding part of the maintenance leader's job. The sorties and hours required to keep our pilots trained or execute a contingency often stretch the ability to manage scheduled maintenance. (United States Air Force 2007, 6-12)

If the unit focuses solely on generating excessive numbers of sorties, the quality, safety, and reliability of the aircraft will suffer. This will eventually lead to decreased sortie production, or worse, not being combat ready when required. Conversely, if the maintenance managers center their attention on fleet management at the expense of sortie production, the aircrews' training will fall short and the entire wing's combat capability will suffer. For these reasons, operations and maintenance schedulers need to build schedules that balance sortie production and fleet management.

The monthly flying and maintenance schedule is the basic building block of a successful operations and maintenance program. A month long period is long enough so units do not “knee jerk” after a bad day, but it is short enough that leadership can identify and correct systemic problems before they significantly affect aircrew readiness. Maintenance leadership reviews maintenance metrics monthly, major commands (MAJCOMs) monitor crew readiness monthly, and each wing reports the number of hours flown to headquarters monthly. For these reasons, executing a successful monthly flying schedule is one of the primary goals for the maintenance and operations groups.

The maintenance group input to the monthly schedule starts after the operations squadron identifies the number required sorties for that month. The number of required sorties includes all sorties for aircrew training, upgrades, exercises, air shows, depot input ferry flights, and all other known requirements. When the Maintenance Group and Operations Group Commanders agree to the number of required sorties and the Wing Commander signs the schedule, the required number of sorties becomes the monthly contract. The monthly contract is the final resolved product balancing the aircrews’ training requirement and the maintenance capability.

After the contract is agreed upon, maintenance schedulers calculate an attrition factor to add scheduled sorties beyond the monthly contract. Attrition factors represent the historical percentage of scheduled sorties lost to causes outside of the unit’s control (United States Air Force 2008, 46). Reasons for canceled sorties include maintenance, operations, supply, air traffic control, sympathy, higher headquarters, other cancels, and weather. The maintenance schedulers apply the total forecasted attrition factor to “ensure fulfillment of the contract” (United States Air Force 2008, 18).

Units that fly large numbers of small aircraft, like fighters and trainers, cancel more sorties for weather than any other cause. Units that fly small numbers of heavy aircraft, like bombers, tend to cancel more sorties for maintenance. For example, the 509th Bomb Wing at Whiteman AFB, Missouri, flies both B-2 bombers and T-38 trainers. For fiscal years 2003-2007, the bomber unit canceled 9.5 percent of the scheduled sorties for maintenance and 4.7 percent for weather. Over the same period, the T-38 unit canceled 6.4 percent of schedule sorties for weather and only 0.5 percent for maintenance.

ACCI 21-165 details how to calculate and apply attrition rates. The attrition rate is simply the five-year monthly average of sorties canceled from each category. A five-year historical attrition profile is normally long enough to account for any seasonal spikes in canceled sorties (United States Air Force 2008, 46). Ideally, the historic attrition rate should not change dramatically from month-to-month. Monthly changes in weather attrition are easy for schedulers to understand; however, month-to-month changes in maintenance attrition are more difficult to justify. For example, between fiscal years 2003-2007 the 509th Bomb Wing' five-year maintenance attrition rates varied from a high of 15.8 percent in December to a low of 6.2 percent in March.

If the actual attrition is less than the predicted attrition while executing a monthly flying schedule, the unit met the contract. If the actual attrition is greater than the predicted attrition, the unit did not meet the contract. ACCI 21-165 includes the following paragraph concerning adjustments to the monthly flying schedule.

> If attrition is less or more than planned, adjustments to the weekly flying and maintenance schedule will be made to prevent over-extending maintenance or

> exceeding the unit's contract. A sortie lost will normally be flown in the same month the loss occurred. (United States Air Force 2008, 46)

Two theoretical failure models can result from using an historical attrition rate calculation. First, if a unit cancels a significant number of sorties in a particular month, the historical attrition rate calculated the following year would be higher. Increasing the attrition rate causes schedulers to increase the scheduled utilization (UTE) rate of the aircraft, which leads to less down time to perform preventative maintenance on the aircraft. Lack of downtime to maintain the fleet can reduce the quality and reliability of the aircraft resulting in more maintenance cancels. More maintenance cancels will increase the historical attrition rate and the process starts over. This self-fulfilling prophecy is informally referred to as the scheduling "death spiral" as depicted in figure 1. Attrition scheduling may force units to over schedule their aircraft and increase the number of canceled sorties.

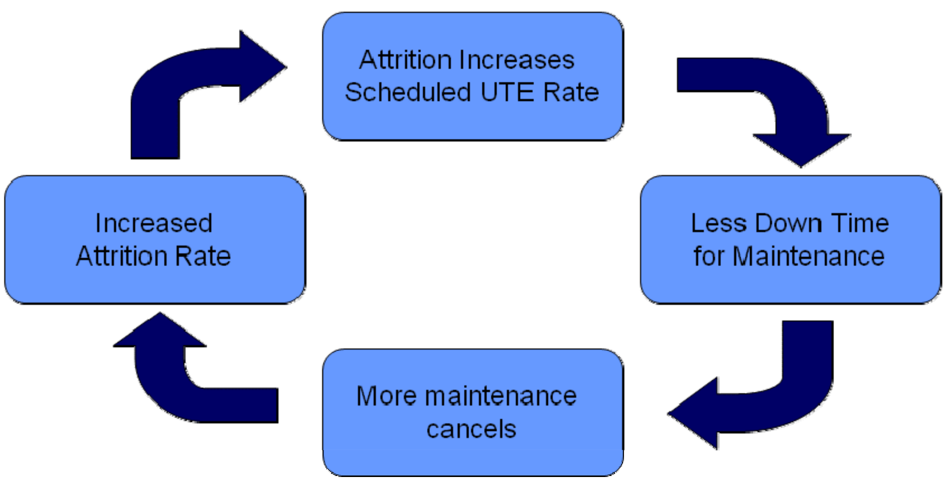

Figure 1. Scheduling Death Spiral
Source: Created by author.

If the units are over scheduling their aircraft and experiencing the wrath of the scheduling death spiral, months with low attrition rates, and therefore a lower scheduled UTE rate, should meet the sortie contract more often than months with a high attrition rate.

The second theoretical failure model is not as easy to visualize. ACCI 21-165 states that “attrition sorties are not substitutes for unit capability shortfalls” (United States Air Force 2008, 46). However, high attrition rates can mask unit capability shortfalls by not focusing attention on the reason for the cancels. It is possible for managers to overlook a systemic problem in the maintenance unit because the high attrition rate allows large numbers of sorties to cancel but still meets the sortie contract. Shortages in work force, spare part availability, high operational tempo or long repair cycles are just a few factors that can lead to canceled sorties. Just because the five-year historical attrition rate is 20 percent does not mean it is acceptable to cancel 20 percent of the sorties in the future. Attrition scheduling could allow units to use historical attrition as a crutch, relying on excess scheduled sorties to mask capability shortfalls. If the units are masking capability shortfalls with excessive attrition, months with high attrition rates should meet the sortie contract more often than months with low attrition rates.

Two additional considerations influence a unit’s ability to meet its monthly sortie contract. They are resistance to change the weekly schedule and focusing solely on flying hours instead of training sorties. Attrition scheduling techniques use historical data to predict future loses, and if applied correctly, there should be no need to make changes to the weekly schedule. However, in reality, there are always unforeseen

circumstances that the short-term schedule could not account for. On the surface, the easy answer is to add more sorties to prevent short-term loses. ACCI 21-165 warns:

> Be aware that aircraft should rarely be "added." If aircraft are added because maintenance cannot provide enough front lines, something else is wrong and most likely the problem is being compounded. There is a domino effect: How many more aircraft will you add to the "broke" pile before you call "knock it off?" (United States Air Force 2008, 7)

If the maintenance units are already including attrition sorties into the schedule, there probably is not excess capability available, and adding aircraft to the schedule to prevent short-term loses will eventually influence the ability to meet long-term goals. If the historical attrition does not correctly predict future loses, there is no back-up plan to prevent short-term loses.

If at the end of the quarter the number of lost sorties exceeds predicted attrition, the Maintenance and Operations Group Commanders negotiate resolution (United States Air Force 2008, 46). The resolution usually includes a "re-flow" of flying hours aimed to recoup losses, but often results in selling hours back to the MAJCOM. Prior to Operations Enduring and Iraqi Freedom, the standard measure of a wing's performance was how well it executed its annual flying hour program. Since the USAF bases the wing's operations and maintenance (O&M) budget on how many flying hours it programs and executes each year, it was widely considered poor management for a wing to execute fewer hours than it programmed. It was common practice for wings to "over fly" the monthly contract early in the fiscal year to get ahead of the flying hour program in case sorties and hours are lost later in the year. Additionally, both operations and maintenance management would go through great lengths to "zero-out" the programmed flying hours in the last week of the fiscal year. When the leadership of the wing focuses

on flying a specific number of hours and not accomplishment of training goals, the aircrews' readiness and fleet management may suffer. However, in the last five years, there has been a move in ACC away from measuring a wing's performance based on flying hours. ACC supplement to AFI 11-201, Flying Hour Program Management, states that "unit flying hour programs will not be overflown by more than 20 hours" and "unit commanders are not required to 'zero out' their annual flying hour program at the end of the fiscal year" (United States Air Force 2007, 6).

While deployed, units rarely miss any tasked sorties. This often leads to arguments at home station why a unit can fly all of its sorties deployed, but cancels up to 20 percent at home station. There are many differences between the deployed environment and home station. The manning percentage and skill-level availability are usually higher while deployed, nobody has any ancillary training taking them off the flightline, and the supply system gives the deployed units priority for parts. Additionally, deployed units do not schedule combat sorties the same way as home-station training sorties. While deployed the Air Tasking Order (ATO), which does not included attrition, drives the flying schedule. The ATO generally tasks the units with a constant and obtainable utilization rate. At home station, operations and maintenance leadership does not view each sortie as critical, and it is common to increase the utilization rate and accept the canceled sorties. However, increasing the utilization rate and letting sorties cancel will result in a disproportionate number of man hours spent recovering the aircraft after each cancel, and lead to more sorties being lost due to work force non-availability.

The performance of the bomber units while deployed shows that with sufficient replacement parts and work force focused on flying every sortie, deployed units can

easily outperform home station operations. Although it is not cost effective for the USAF to significantly increase work force or spare parts availability at home station, it can change its scheduling techniques to focus on meeting the flying squadron's monthly contract. This research explores if the current USAF attrition scheduling techniques ensure monthly sortie contracts are met as predicted by ACCI 21-165 (United States Air Force 2008, 18). Additionally, this research seeks to determine if attrition scheduling results in units either over scheduling their aircraft or masking capability shortfalls.

Primary Research Question

Is the current USAF scheduling technique of using a five-year historical attrition rate an effective way to ensure the bomb wings' consistently meet their monthly sortie contracts?

If using a five-year historical attrition is an effective way for bomb wings to consistently meet the sortie contract, the probability of meeting the sortie contract should not be related to the magnitude of the attrition dictated by the five-year historical attrition. To answer the primary research question, this research tested the following hypothesis.

Research Hypothesis

USAF bomber fleet experiences a statistically significant difference between months with high and low scheduled attrition with respect to the percent of months that each meets the sortie contract.

Subsequent Research Questions

If the research supports the hypothesis, the research addresses the following questions in order to make any relevant recommendations.

1. Can the difference in high and low attrition categories meeting the sortie contract be attributed to over scheduling of the aircraft or from masking a unit capability shortfall?

2. Do all of the different types of bombers experience the same statistically significant difference between months with high and low scheduled attrition with respect to the percent of months that each meets the sortie contract?

3. Do each of the main operating bases (MOBs) experience the same statistically significant difference between months with high and low scheduled attrition with respect to the percent of months that each meets the sortie contract?

4. Is there a better scheduling framework that can increase the probability of meeting the monthly contract?

Definitions

Listed below is a brief glossary of key terms relevant to this study. While most come directly from the AFIs, some terms can obtain slightly different connotations depending on the context. The descriptions below represent the definitions of the key terms used in the context of this study.

Attrition: Losses expected based on historical data. Sorties added by maintenance scheduling to a unit's sortie contract to allow for expected losses due to maintenance, operations, supply, air traffic control, sympathy, higher headquarters, other cancellations, and weather cancellations. If attrition is less or more than planned, operations and

maintenance schedulers should adjust the schedule to prevent overextending maintenance and/or to stay within the unit's sortie flying-hour program. Attrition sorties are not substitutes for capability shortfalls; they are additive to the contract to ensure mission goals are met. The operations and maintenance units will normally attempt to make up sorties in the week or month the loss occurred. If at the end of a quarter, losses exceed attrition figures, the Operations Group and Maintenance Group commanders will come to an agreement on how the shortfall will be corrected (United States Air Force 2008, 55).

Cancellation: A planned sortie that does not fly for any reason including maintenance, operations, supply, air traffic control, sympathy, higher headquarters, weather, and other uncategorized causes (United States Air Force 2008, 55).

Maintenance Cancel: A sortie that did not takeoff due to aircraft discrepancies, unscheduled maintenance, or for actions taken for maintenance consideration (United States Air Force 2008, 31).

Monthly Contract: The number of sorties required for the month, agreed upon by the Operations Group and Maintenance Group commanders (United States Air Force 2008, 18).

Monthly Schedule: The schedule, approved by the Operations and Maintenance Group commanders and signed by the Wing Commander, which represents the total number of sorties scheduled for the month. The monthly schedule includes the required sorties (contracted) and the attrition sorties.

Red Ball Maintenance: The maintenance performed on an aircraft to fix a malfunction reported while attempting to launch.

Spare Aircraft: An aircraft specifically designated on the flying schedule to replace aircraft that cannot fly its sortie (United States Air Force 2008, 59).

Utilization Rate: The rate representing the number of sorties per aircraft per month (United States Air Force 2006, 59).

Assumptions

There are two assumptions required to conduct this research. First, the research relies heavily on historic data. To be relevant, the research assumes that each Bomb Wing followed the existing regulations and recorded the data correctly. Second, the research assumes that the operations schedulers designed the monthly contract to meet the flying squadron's monthly training requirement.

Limitations

To narrow the focus of the research, this thesis applied two limitations. First, this research is only applicable to USAF Bomb Wings, specifically the 509th Bomb Wing, Twenty-eighth Bomb Wing, Seventh Bomb Wing, Second Bomb Wing and Fifth Bomb Wing. If lowering the attrition rate increases a flying squadron's ability to meet the required number of sorties each month, USAF bomber units will display the strongest correlation. Bomber units tend to fly fewer sorties each month and require more maintenance man-hours per flying hour than fighter and attack aircraft. Similar results are possible with other aircraft in other wings, but additional research is required.

Second, there are significant differences between deployed and home station operations. Since deployed operations do not appear to display the same problem

meeting the ATO, this research will only involve home station training sorties, and therefore any results are only applicable to home station training operations.

Delimitations

There are two delimitations associated with this research. First, meeting the contracted number of training sorties for the month does not necessarily equate to meeting all of the aircrew training requirements for the month. There are factors outside of maintenance control that impact aircrew training such as, access to bombing ranges, tanker support for aerial refueling, and availability of other external customers. This research only addresses how to provide the contracted number of sorties, and does not include any algorithms or modeling for efficient sortie utilization.

Second, this research does not examine the impact of deployed operations on home station's ability to execute a monthly flying schedule. While deployed, some units may tend to delay maintenance actions until the aircraft returns to home station. Similarly, it is plausible that units select aircraft with good flying histories for deployment while leaving the aircraft with poor histories at home station. It is nearly impossible to evaluate how units selected aircraft for past deployment and the impact of those selections on home station operations. Additionally, bomb squadrons normally have a higher aircrew to aircraft ratio deployed than at home station. This could reduce the required UTE rate home station, which in turn, could make meeting the monthly contract easier. Therefore, this research is limited to evaluating the success executing home schedules without regard for a possible impact from deployed operations.

Significance of Thesis

The USAF has changed dramatically since the end of the cold war, however, the techniques for scheduling monthly training sorties have not. Even in the last five years, the focus of ACC has moved away from measuring a wing's performance based on flying hours and towards judging on how well it executes its training. With reduced manpower and increased deployments, the maintenance and operations units need to take full advantage of every sortie scheduled, and not accept a ten to twenty percent loss rate just because that's the way it's always been done. If this research supports the hypothesis stated earlier, changes to the maintenance and flying scheduling techniques can lead to more cost efficient use of manpower and resources combined with a more effective execution of the aircrews' training requirements.

Some relevant literature is devoted to aircraft scheduling techniques, including military doctrine and regulations, changes in civilian airlines procedures to become more cost effective, and literature applying operations research in the emerging field of disruption management. Chapter 2 examines this literature, finds information gaps in the record that this research fills.

CHAPTER 2

LITERATURE REVIEW

This chapter comprehensively summarizes and briefly evaluates existing literature, identifies gaps in the record, and discusses the significance of this study relative to the existing record.

Significant Literature

Three broad categories of literature are relevant to this study. First, USAF doctrine and AFIs regulate current monthly scheduling techniques and capture best practices from the operational wings. Next, there are numerous publications cataloging the civilian airline industry's focus on reducing costs and improving efficiency though better scheduling. Finally, there is a significant amount of recent literature applying operations research in the emerging field of disruption management.

Air Force Specific Documentation

USAF doctrine and AFIs cover the monthly scheduling processes. A distinction needs to be made on the differences between doctrine and instructions. According to Air Force Doctrine Document 1, Basic Doctrine, "air and space doctrine is a statement of officially sanctions beliefs, warfighting principles, and terminology that describes and guides the proper use of air and space forces in military operations" (United States Air Force 2003). Doctrine is not directive; rather it consists of fundamental principles that guide military forces. AFIs on the other hand are regulatory. Printed in bold capital letters on the cover page of every AFI is the statement "COMPLIANCE WITH THIS

PUBLICATION IS MANDATORY" (United States Air Force 2006). In cases where doctrine differs from AFIs, the regulatory instruction takes precedence.

Doctrine

USAF doctrine is broken into three distinct levels: basic, operational and tactics, techniques, and procedures (TTPs). Air Force Doctrine Document 2-4, Combat Support, lists "supporting training operations" as one of the peacetime priorities included in readying the force for combat operations (United States Air Force 2005, 15). This relatively vague statement is the only reference to executing home station training sorties in either basic or operational level doctrine. Since TTPs are doctrine written for decision makers at the tactical level, there is more, but still limited, written in TTPs concerning monthly scheduling techniques. Air Force Tactics Techniques and Procedures (AFTTP) 3-21.1, Aircraft Maintenance, contains one chapter dedicated to maintenance and flying scheduling.

AFTTP 3-21.1 states, "the number one priority in aircraft maintenance management is ensuring the long-term health of the fleet . . . and maintenance decisions should be made based on overall fleet [readiness] and operational requirements" (United States Air Force 2007, 6-1). The TTP breaks the scheduling techniques into two categories, scheduled maintenance and flying scheduling.

Maintainers perform scheduled maintenance actions based on prescribed intervals, usually flying hours, number of sorties, and calendar days. Large bomber fleets with thousands of scheduled maintenance actions must be managed aggressively to ensure the scheduled maintenance action is completed on time. In accordance with AFTTP 3-21.1, "it is always beneficial to consolidate as many scheduled maintenance

actions as possible into one scheduled down time" (United States Air Force 2007, 6-1). Maintenance managers need to schedule down time for scheduled maintenance while still meeting the operational requirements on the flying schedule.

The ability to balance fleet health with executing the flying schedule is the most demanding part of the maintenance leader's job. The sorties and hours required to keep the aircrew trained often stretch the ability to manage scheduled maintenance (United States Air Force 2007, 6-12). Key to accomplishing this feat is for maintainers to understand the aircrews' training requirements and for aircrews to understand the scheduled maintenance requirements. Additionally, both operations and maintenance schedulers need to exercise prudent scheduling discipline, paying special attention to adding aircraft to the flying schedule. Once the schedule is approved, maintenance and operations leadership should not add sorties or aircraft without understanding the associated cost (United States Air Force 2007, 6-13). If the number of sorties scheduled already stretches the maintenance unit's sortie production capability, adding more sorties to make-up for previous losses can quickly push them past the breaking point. Furthermore, adding aircraft to the flying schedule to make up for aircraft that are "hard-broke" compounds an already bad situation. Since the work force is pulled away from repairing the already broken aircraft to inspect, service, launch, and recover additional aircraft, repair actions are delayed. If the original broke aircraft is scheduled to fly later in the week, the delayed repair actions can result more lost sorties down the road. This is commonly referred to as the "death spiral" where too many aircraft are broken, and repair actions cannot be accomplished to meet the following day's schedule (United States Air

Force 2007, 6-13). To prevent the death spiral, schedulers add attrition to the monthly contract to account for losses outside of the unit's control.

AFTTP 3-21.1 contains the following paragraph concerning application of attrition sorties:

> Sortie attrition must be accounted for in the annual, quarterly, monthly and weekly flying schedule. Attrition is designed to account for a certain number of scheduled sorties that will be lost due to various reasons. (Note: Attrition included in the [flying hour program] for non-effective sorties is different from scheduling attrition.) Attrition is calculated based on historic averages by month. Weather is the most common reason for sortie losses. Therefore a higher attrition rate will occur in months with typically bad weather. Pay close attention to the amount of sorties the [operations squadron] schedulers are building into the schedule. If the [operations squadron] schedulers are scheduling more sorties than the calculated attrition dictates you may be forced to commit more aircraft or fly three-go days to achieve the schedule. Additive sorties above attrition could be the difference between a one-go Friday and a two-go Friday. Build the schedule around the historical attrition and fly the plan. (United States Air Force 2007, 6-21)

This relatively short paragraph contains two points that require further discussion. First, AFTTP 3-21.1 states that weather is the most common reason for sortie losses. However, as stated in chapter 1, bomber units typically experience more canceled sorties due to maintenance than to weather. Second, the paragraph addresses what may happen if the operations squadron schedulers apply an inflated attrition rate. Specifically, the maintenance unit may be forced to commit more aircraft to the flying schedule and reduce the amount of down time available to accomplish scheduled maintenance. The analysis of literature section of this chapter will discuss both of these points in detail.

Air Force Instructions

AFI 21-101, *Aircraft and equipment maintenance management*, and ACCI 21-165, *CAF: Aircraft flying and maintenance scheduling procedures*, both cover attrition calculation and monthly scheduling procedures applicable to the USAF bomber fleet.

ACCI 21-165 provides the most thorough instruction to build and execute a monthly schedule. It requires monthly flying schedules to include predictable maintenance factors based on historical data along with other inputs, such as flow times for maintenance, turnaround times and parts replacement schedules from the long-range maintenance plan. ACCI 21-165 states that these scheduled "maintenance events should be consolidated during a single down period to the greatest extent possible" (United States Air Force 2008, 17). To ensure that there is enough down time to accomplish all of the scheduled maintenance, schedulers need to include all known operational events including exercises, deployments, and surges on the monthly schedule. When the Operations and Maintenance Group commanders agree on the number of sorties required, and the Wing commander approves it, that agreement becomes the monthly sortie contract. The contract specifies the number of sorties and flying hours required and represents the final resolved product between operational requirements and maintenance capabilities. Schedulers then apply the total forecasted attrition factor to the required sorties to ensure fulfillment of the contract (United States Air Force 2008, 18).

Attrition factors represent historical percentage of scheduled sorties lost to causes outside unit control. In accordance with ACCI 21-165, the Maintenance Data Systems Analysis (MDSA) section calculates the attrition rate, A, for each flying squadron separately using equation 2.1.

$$A = 1 - \frac{\sum S_f}{\sum S_{sch}} \tag{2.1}$$

Where $\sum S_f$ represents the sum of the sorties flown for the particular month over the last five years, and $\sum S_{sch}$ equals the sum of the sorties scheduled for the same month over the last five years. A five-year average is used to ensure seasonal variations are considered to determine a basis for attrition (United States Air Force 2008, 46).

Similar to the TTP, ACCI 21-165 emphasizes that “attrition sorties are not substitutes for unit capability shortfalls, they are added to the contract to mitigate scheduling turbulence to facilitate that unit’s mission goals are met” (United States Air Force 2008, 46). Additionally, ACCI 21-165 states that the monthly flying and maintenance plan will clearly identify attrition sorties for planning purposes. However, AFI 21-101 states “do not assign attrition sorties to a specific aircrew/mission for the monthly planning process” (United States Air Force 2006, 176).

If attrition is more or less than planned, adjustments to the weekly flying and maintenance schedule will be made to prevent over-extending maintenance capability or exceeding the monthly contract. A sortie lost will normally be flown in the same month the loss occurred (United States Air Force 2008, 46).

The historical attrition is broken into the following categories: maintenance, operations, supply, other, air traffic control (ATC), sympathy, headquarter directed exercise (EXH), local exercise (EXL), headquarter (HQ) cancels, and weather. Units may make a conscious decision, with HQ approval, to deviate from statistical attrition rates calculated from historical averages (United States Air Force 2008, 46).

Table 1 recreates the example of an attrition calculation from ACCI 21-165.

Table 1. Attrition Computation Example

Reason for cancel	5-year average rate
Maintenance	.02
Operations	.01
Supply	.01
Other	.01
ATC	.01
Sympathy	.01
EXH	.00
EXL	.01
HQ	.01
Cancels Attrition Factor	.09
Weather	.03
Total Attrition Factor	**.12 or 12%**

Source: United States Air Force. *Air Combat Command instruction 21-165, CAF: Aircraft flying and maintenance scheduling procedures* (Washington, D.C: U.S. Government Printing Office, 2008), 46.

To continue the example for applying the attrition rate calculated in table 1 to a monthly contract of 1,000 sorties, schedulers use equation 2.2.

$$\frac{S_r}{(1-A_t)} = \frac{1{,}000}{(1-0.12)} = 1{,}136.36 \approx 1{,}137 \qquad (2.2)$$

where:

S_r = sorties required (1,000 in this example)

A_t = total attrition rate (12% in this example)

The fraction of a sortie is always rounded up, so in this example, based on a historical attrition of 12 percent the unit can expect to lose 137 sorties to meet the required 1,000 sorties for the month.

Civilian Airline Scheduling Practices

Over the last decade, scheduling of civilian airlines has focused on incorporating the tenets of lean management. To draw a correlation to lean manufacturing, think of all efforts associated with generating an aircraft to fly including pre-flight inspection, servicing, configurations and red ball maintenance, as steps in a manufacturing process. Each action needs to be coordinated with the others, and to make the process run smoothly, lean manufacturing techniques can be used to streamline the operation, reduce cost and eliminate waste.

Waste is described as any activity that absorbs resources but does not produce any value (Womack and Jones 2003, 15). To continue the manufacturing analogy, instead of expecting a certain percentage of products to require re-work, management should be focused on making it error free the first time. In aircraft generation, this means to fly the schedule and expect no cancellations. Obviously, this is a lofty goal and does come with a price.

Analyzing the cost of quality is common in the manufacturing industry and can generally be categorized into four types (Chase, Aquilano and Jacobs 2001, 269-270):

1. Appraisal Cost. Costs associated with the inspection process. For aircraft generation this cost is pre-existing in our quality assurance function.

2. Prevention Cost. The sum of all the costs to prevent defects.

3. Internal Failure Cost. Costs for defects incurred within the system such as scrap, re-work, and repair. In this example, this is the cost to generate another aircraft if the first aircraft is canceled. The cost is mostly measured in the manpower diverted from other task to generate the aircraft.

4. External Failure Costs. Cost for defects that pass through the system. For the aircraft generation model, this is when there is not another aircraft available to fly and the sortie is canceled.

To prevent over utilization of the aircraft and the resulting waste of manpower, schedulers can apply capacity planning concepts. This is the "level of capacity for which the process was designed and thus is the volume of output at which average unit cost is minimized" (Chase, Aquilano and Jacobs 2001, 270).

To minimize costs while still meeting customer demands for flights, the civilian airline industry has armed its schedulers with sophisticated optimization tools to improve decision making. Barnhart and Cohn (2004) break the optimization process down into four sequential steps. First and foremost is schedule design. According to Barnhart and Cohn (2004, 4), "the flight schedule . . . is the single most important product of an airline". The schedule design includes what markets the airline will compete in, how many flights will be flown there and at what time of day. The schedule design is the base line that all of the flight operations are focused on achieving. After the schedule design is set, the next step to optimize the flight schedule is to determine which aircraft in the airline's fleet will fly the routes. Then, the schedulers need to make the aircraft maintenance routing decision. Maintenance routing ensures that the aircraft assigned to the route have maintenance capabilities to cover scheduled and unscheduled maintenance requirements. The final step in optimizing the flight schedule is crew scheduling which needs to incorporate the right combination of crew experience and programmed down time to meet crew rest requirements.

Disruption management

As discussed earlier in this chapter, the USAF monthly scheduling regulations require schedulers to include attrition sorties for expected loses. Another way to look at attrition scheduling techniques is the USAF requires a certain number of canceled sorties each month to stay on schedule. In the civilian airline industry, management seeks to minimize expenses by eliminating waste in the flight schedules. However, when weather, maintenance or aircrews cause a disruption, and there is no slack built into the schedule, management has to revise the schedule to minimize the impact to the customer, maintenance and aircrew. To best address how to get the schedule back on line after a variation, the field of Airline Disruption Management has emerged (Kohl, Ross and Tiourline 2004).

According to Kohl, Ross and Tiourline (2004), there are three objectives to successful disruption management. First, it must deliver the customer promise and fulfill the contract the airline has made with the customer. Second, the plan to get back on schedule must minimize the cost to the airline. Finally, a successful disruption management plan returns to the original schedule as soon as possible after a disruption. A similar approach to disruption management is achieved with the goal-programming model.

Yu and Qi (2004) produced an excellent and extremely thorough set of models dealing with disruption management. Most relevant to this thesis is their disruption management model based on a goal-programming framework as a way to handle multiple criteria in decision making problems. It is beyond the scope of this research to explore the intricacies of their model; however, understanding the following introduction to goal

programming is important to understand how it can be applied to USAF scheduling practices.

In a situation where two or more criteria must be evaluated while developing a response to a disruption, each criteria must be measured by different metrics. To use goal programming to solve a problem with multiple criteria, management must set a goal for each criteria and then try to minimize the gap from the goal for each criterion. In most cases, a single solution cannot optimize all criteria, but the purpose of goal programming is to minimize the distance to these goals (Yu and Qi 2004, 32).

Suppose a mathematical programming problem can be identified with equation 2.3.

$$\begin{aligned} \min f(x) \\ \text{subject to } x \in X \end{aligned} \tag{2.3}$$

In equation 2.3, x is the decision variable and X is the feasible set. Assume there is an optimal solution, x^o, to equation 2.3. When a disruption occurs, it can be either a parameter change in the objective function or a change to the feasible set. After a disruption, the objective function becomes $\hat{f}(x)$, and the feasible set becomes $\hat{X}$. Here, the purpose of goal programming is to find a solution to the new problem that is as close to optimal as possible with respect to multiple criteria. Yu and Qi identify two general criteria associated with a disruption (2004, 33).

The first criteria is minimizing the solution deviation, in other words finding a solution, x, that is as close to x^o as possible to reduce the possible deviation cost. The problem can be expresses with equation 2.4.

$$\begin{aligned} &\min g(\mathrm{a}^+, \mathrm{a}^-) \\ &\text{subject to } x \in \hat{X} \\ &\qquad x + a^+ - a^- = x^o \\ &\qquad a^+, a^- \geq 0 \end{aligned} \tag{2.4}$$

In equation 2.4, a^+ and a^- represent the deviation from x^o to the new solution x, and $g(\mathrm{a}+, \mathrm{a}-)$ is a function used to evaluate the deviation cost. The goal of equation 2.4 is to find a new solution as close to the original plan as possible, given the new feasibility constraint $x \in \hat{X}$.

The second general criteria identified by Yu and Qi (2004, 33) is minimization of the new objective function represented in equation 2.5.

$$\begin{aligned} &\min \hat{f}(x) \\ &\text{subject to } x \in \hat{X} \end{aligned} \tag{2.5}$$

Equation 2.5 only seeks to minimize the objective function subject to the new feasibility constraint without respect to the possible deviation cost between x and x^o.

Independently, equations 2.4 and 2.5 can be handled relatively easily as single criterion optimization problems. However, when managing disruptions to monthly flying schedules, it is not feasible to develop a response that does not have a goal of meeting the original requirement while minimizing the solution deviation. This does not mean it is possible to find a solution that can completely satisfy both criteria. By looking at each criterion as a goal instead of a requirement, managers can use a goal-programming model to find a good balance between the two.

Yu and Qi (2004) introduce the following lexicographic goal-programming structure with varying priority levels as one method to handle multiple goals in a single optimization model. Suppose management places the minimizing the solution deviation as a higher priority than minimizing the new objective function. In other words, the

solution needs to find an optimal solution to equation 2.4. If there are multiple such optimal solutions, then the one that minimizes equation 2.5 is the best choice. This lexicographic model can be summarized in equation 2.6.

$$\begin{aligned} &\text{Min } \mathit{Lex}\ \mathit{P1:}\ g(\mathrm{a}^{+},\mathrm{a}^{-}) \quad \mathit{P2:}\ \min \hat{f}(x) \\ &\text{subject to } x \in \hat{X} \\ &\qquad x + a^{+} - a^{-} = x^{o} \\ &\qquad a^{+}, a^{-} \geq 0 \end{aligned} \tag{2.6}$$

Alternatively, management may decide that minimizing the objective function is a higher priority than minimizing the solution deviation as shown in 2.7.

$$\begin{aligned} &\text{Min } \mathit{Lex}\ \mathit{P1:}\ \hat{f}(x) \quad \mathit{P2:}\ \min\ g(\mathrm{a}^{+},\mathrm{a}^{-}) \\ &\text{subject to } x \in \hat{X} \\ &\qquad x + a^{+} - a^{-} = x^{o} \\ &\qquad a^{+}, a^{-} \geq 0 \end{aligned} \tag{2.7}$$

Obviously, equations 2.6 and 2.7 assume that a solution, *x*, can be found in the new feasible set, $\hat{X}$. This may not be the case, and it might be impossible to develop a solution that can meet the highest priority goal with the new feasible set. However, it may be possible to develop a partial solution that nearly meets the highest priority. To allow for partial solutions, Yu and Qi extend the lexicographic formulation by defining the highest priority goal to satisfy the feasibility constraint (2004, 35) as shown in equation 2.8.

$$\begin{aligned} &\text{Min } \mathit{Lex}\ \mathit{P1:} h(\beta^{+},\beta^{-}) \quad \mathit{P2:}\ \min g(\mathrm{a}^{+},\mathrm{a}^{-}) \quad \mathit{P3:}\ \hat{f}(x) \\ &\text{subject to } x + \beta^{+} - \beta^{-} \in \hat{X} \\ &\qquad x + a^{+} - a^{-} = x^{o} \\ &\qquad a^{+}, a^{-}, \beta^{+}, \beta^{-} \geq 0 \end{aligned} \tag{2.8}$$

In equation 2.8, β^{+}, β^{-} measure the gap for the goal of finding a solution, *x*, in the new feasible set $\hat{X}$, and $h(\beta^{+},\beta^{-})$ is a function that measures the cost of not finding a solution in the new feasible set. In plain English, equation 2.8 seeks to find a solution

that satisfies the feasibility constraints as much as possible, then minimizes the solution deviation and finally optimizes the new objective function.

Using lexicographic goal programming model allows managers to effectively deal with partial solutions by enabling violation from the original constraints, and generating multiple acceptable solutions by changing the ways and priorities of goals (Yu and Qi 2004, 34).

Analysis of Literature

The USAF has documented a limited number of TTPs and instruction concerning the calculation and application of attrition. However, all of the documentation is based on the fundamental theory that applying a historical attrition rate to future schedules is an effective way to ensure the units meet their sortie contract.

The civilian airline industry, driven by the desire to cut costs, eliminate waste and improve efficiency, has optimized flight schedules while accounting for maintenance and crew considerations. Additionally, the emerging field of disruption management has assisted the airline industry in optimizing their flight schedules and reducing costs. Some generic disruption management models can effectively deal with partial solutions and generate multiple paths to recover from a disruption.

Gaps in the Record

The most notable gap in the record is the absence of any USAF operational level doctrine addressing goals, operational design and desired end state of flying schedules. The tactical doctrine correctly identifies the difficulty in balancing fleet health with aircrew training requirements. Without nesting into higher doctrine, the impact of not

balancing fleet health with aircrew training requirements is not addressed and these portions of the TTPs are often overlooked.

Additionally, there is no literature that addresses using disruption management techniques in the USAF to make schedules more efficient and effective. It is assumed at the tactical level that adding historical attrition is the best way to ensure that units meet their monthly contract.

Significance of Thesis in relation to existing literature

This thesis effectively fills both of the gaps identified above by analyzing if using historical attrition is an effective way for the USAF to ensure it consistently meets its monthly sortie contract. In addition, it applies disruption management techniques to determine if there is a better scheduling framework that can increase the probability of meeting the monthly contract.

As shown in this chapter, there is some relevant literature on civilian airlines optimizing their flight schedule and applying disruption management techniques to minimize the impact to the operation if the schedule is not executed as planned. However, the current record does not adequately address if using historical attrition rates is an effective way to meet the monthly contract consistently. Chapter 3 develops the methodology to address if attrition scheduling is an effective way to meet the monthly contract consistently.

CHAPTER 3

RESEARCH METHODOLOGY

Chapter 2 identified that absence of existing literature concerning the effectiveness of attrition scheduling. This purpose of this chapter is to describe the research methodology used to answer the primary research questions: Is the current USAF scheduling technique of using a five-year historical attrition rate an effective way to ensure the bomb wings' meet their monthly sortie contracts consistently? The first section of this chapter discusses the research model. Section 2 identifies the participants in the research. Section 3 outlines the procedures, including variables, controls and method of data collection. Section 4 describes the data analysis, including descriptive statistics and identification of the test statistic. Finally, section 5 discusses quality considerations required for this research methodology.

Research Model

This research aims to determine what effect the scheduled attrition rate has on USAF bomber units meeting their monthly sortie contract. While experimental research methods could test the hypothesis, current operations tempo and training requirements make it impractical to manipulate independent variables individually at each of the bomber bases to gather data. Instead, this research followed a causal-comparative, or ex post facto, research model. Causal-comparative research relies on historical information to determine the cause, or reason for existing differences (Westmeyer 1994, 54). More specifically, this is a prospective causal-comparative research model since it starts with the cause, attrition rates, and investigates the effects, meeting the sortie contract (Gay

1996, 322). The strengths and weaknesses of a prospective causal-comparative research model are addressed later in this chapter. The next step to describe the research methodology is to identify the participants.

Participants

The participants for this research are the USAF bomb wings at Minot AFB, Barksdale AFB, Whiteman AFB, Dyess AFB, and Ellsworth AFB. Since this thesis applies a causal-comparative research model, only historic data was available. The sample used to make inferences on the population were the monthly flying schedules for the participants covering the months from January 2007 through December 2008 with the following exceptions. Data was not available from Minot AFB for August 2008 and October 2008 through December 2008. Whiteman AFB was only able to provide data for January 2008 through December 2008. The data for Whiteman AFB also included an extensive safety stand down following an aircraft mishap making the data for March 2008 unusable. Additionally, the year-end fly out artificially skewed Whiteman AFB's scheduled attrition making September 2008 data unusable. As discussed in the limitations section of chapter 1, this research is limited to only home station training schedules, therefore, deployed data was not included for the participants. This research gathered data from a total of 102 months for the sample.

Procedures

The basic causal-comparative design involves selecting groups differing on some independent variable and comparing them on some dependent variable. Although the research does not manipulate the independent variable, it is possible to exercise some

control measures (Gay 1996, 325). This section will describe the independent and dependant variables, discuss the procedures to control extraneous influences, and explain the data collection method.

Variables

As discussed in chapter 1, the maintenance schedulers apply a historical attrition rate to ensure the unit meets the sortie contract. The independent variable for this research was the scheduled monthly attrition rate for each month in the sample. To assist in the data analysis discussed later in this chapter, the research divided the sample into two categories. The "high" category includes the top 50 percent of sample with respect to scheduled attrition rate. Similarly, the "low" category represents the bottom 50 percent of the sample with respect to attrition rate.

Also discussed in chapter 1, executing a successful monthly flying schedule is one of the primary goals for the maintenance and operations groups. Therefore, the dependant variable was whether each participant month met the monthly contract. This research categorized the variable into two groups, "yes" or "no." Two numbers determine which category each participant month falls; the number of sorties required and the number of sorties flown. If the number of sorties flown minus the number of sorties required is negative, the participant did not meet the monthly contract and is categorized as a "no." If the number of sorties flown minus the number of sorties required is a non-negative number, the participant met the monthly contract and is categorized as a "yes." This may seem like a simple calculation, but there are other extraneous variables that require control in order to delineate the effect of the independent variable on the dependant variable.

Control

Control refers to steps taken to remove the influence of extraneous variables that might affect the dependant variable (Gay 1996, 344). This research controls for the following extraneous variables.

During the execution of the monthly schedule, units often add sorties to the contract to make up for losses earlier in the month. These added sorties artificially inflate the number of sorties flown for the month; therefore, the added sorties are extraneous. To control for the added sorties, the number of added sorties, S_{add}, is subtracted from the number of sorties flown, S_f, as shown in equation 3.1. The result is the adjusted sorties flown.

$$\text{Adjusted Sorties Flown} = S_f - S_{add} \tag{3.1}$$

By calculating the adjusting the sorties flown, the research removed the impact of the added sorties from the units' ability to meet their sortie contract.

The final control variable is the difference in aircraft type inside of the population. While the population consisted of bombers, B-52s may perform differently than B-1s, which may be different from B-2s. To control this extraneous variable, the research formed homogenous subgroups for each aircraft type. This enabled analysis to determine if the independent variable affects the dependent variable differently for all three values, or aircraft type, of the control variable. Subgroups also determine if Dyess AFB B-1s perform differently than Ellsworth AFB B-1s.

The dependant variable was whether each participant month met the monthly contract. To determine if a unit's flying month met the sortie contract, subtract the number of sorties required form the adjusted number of sorties flown as in equation 3.2.

$$\text{If } [S_f - S_{add}] - S_{req} < 0 \tag{3.2}$$

then y = "no"
else y = "yes"

Method of Data Collection

The Maintenance Operations Squadrons (MOS) at each base maintains the data required for this research. The number of sorties flown, S_f , and added sorties, S_{add}, are available for each month in the Core Automated Maintenance System (CAMS). The number of sorties required, S_{req} , and the scheduled attrition is kept in the monthly schedule historical record maintained in the Plans & Scheduling (P&S) element in each MOS. The next section of this chapter discusses the analysis of the data.

Data Analysis

The first step of the data analysis was to describe the data to ensure the research applies the correct test statistic. Nominal measurement is the process of grouping participants into categories with respect to some attribute or property (Glass and Hopkins 1996, 7). As presented earlier in this chapter, this research categorizes the independent and dependant variables into distinct categories. This research used nominal data, but to be more specific, this research categorizes the independent variable into artificial categories and the dependant variable into true categories. According to Gay (1996, 420), artificial categories are categories which are operationally defined by the researcher. Conversely, true categories are categories into which participants naturally

fall, independent of the research study. After describing the characteristics of the data, the next step was to apply descriptive statistics.

Descriptive Statistics

This research used descriptive statistics to describe a relatively large set of data in a concise and uniform method. The descriptive analysis should not be used to make inferences on the population or draw correlations. This research calculated eight descriptive statistics for the entire bomber fleet. Additionally, the same descriptive statistics were calculated for sets representing just the B-52 fleet, the B-1 fleet and the individual MOBs. Since Whiteman AFB is the only base with B-2s, Whiteman set also completely represents the B-2 set. Chapter 4 includes a table summarizing the following descriptive statistics.

1. Number of months: indicates the sample size for each category. This is where data availability exceptions discussed earlier in this chapter were quantified.

2. Overall attrition rate: calculated as one minus the quotient of total number of sorties scheduled for the set divided by the total number of sorties required for the set.

3. Median attrition rate: the point where half of the months in the sample had higher scheduled attrition and half had lower scheduled attrition.

4. Attrition range: the minimum and maximum monthly attrition rate for the set.

5. Percent of months that met goal, overall, low & high: The percent of months that met the sortie contract for the entire set and for the “low” and “high” attrition categories for the set.

The next step is to choose a test statistic to test the null hypothesis.

Null Hypothesis

To support the research hypothesis identified in Chapter I, this research tested the converse, also known as the null hypothesis. If the research hypothesis is true, the sample data will tend to support rejection of the null hypothesis, and the probability of making an incorrect decision is equal to alpha, α, a probability specified in setting up the rejection region (Mendenhall 1979, 175). This research tested the following null hypothesis:

Null Hypothesis, H_o: USAF bomber fleet does not experience a statistically significant difference between months with high and low scheduled maintenance attrition with respect to the percent of months that each meets the sortie contract.

Test Statistic

To test the null hypothesis, this research determined if the observed differences in the participants are significant enough to infer the same difference is true for the population. The chi square, χ^2, is a test of significance which is appropriate when the data represent a nominal scale and the categories are either true or artificial (Gay 1996, 483). A standard χ^2 goodness-of-fit test can determine whether the observed proportions in two or more categories differ significantly from theoretically expected proportions. However, for this research, there were no theoretically expected proportions. The null hypothesis predicted no difference in the percent of times each category met the monthly sortie contract. Since the research compares categories to each other instead of a theoretically expected proportion, the appropriate test statistic was the chi-squared test of association (Glass and Hopkins 1996, 336).

Table 2 represents a 2x2 contingency table used to calculate χ^2. If the data supports the null hypothesis, the percentage of months that meet the sortie contract should not vary much between the maintenance attrition categories.

Table 2. Contingency Table

Met Sortie Contract, r	***Maintenance Attrition Category, c*** *Low*	*High*	***Row Totals***
Yes	n_{11} P_{11}	n_{12} P_{12}	$n_{1\bullet}$ $100\hat{\pi}_{1\bullet}$
No	n_{21} P_{21}	n_{22} P_{22}	$n_{2\bullet}$ $100\hat{\pi}_{2\bullet}$
Column Totals	$n_{\bullet 1}$	$n_{\bullet 2}$	$n_{\bullet\bullet}$

Source: Recreated from Gene V.Glass and Kenneth D. Hopkins. *Statistical methods in education and psychology*. 3rd. (Boston: Allyn & Bacon, 1996), 335.

Note: The frequencies (n_{rc}) in each column are divided by the number of observations in that column ($n_{\bullet c}$) and multiplied by 100 to find the percentage (P_{rc}) of the observations in each column that fall into each row. $100\hat{\pi}_{r\bullet}$ represents the percentage of $n_{\bullet\bullet}$ that falls in row r.

A spreadsheet uses the data from table 2 to compute χ^2 using equation 3.3.

$$\chi^2 = \sum_{r=1}^{R}\sum_{c=1}^{C}\frac{n_{\bullet c}}{100}\frac{(P_{rc} - 100\hat{\pi}_{r\bullet})^2}{100\hat{\pi}_{r\bullet}} \tag{3.3}$$

The expected number of observations for each cell, F, if the null hypothesis is true is calculated using equation 3.4.

$$F_{rc} = \frac{n_{r\bullet} \times n_{\bullet c}}{n_{\bullet\bullet}} \tag{3.4}$$

The value of χ^2 increases as the observed proportions within a given row differ among the groups being contrasted (Glass and Hopkins 1996, 334). This research rejects the null hypothesis if the value of χ^2 from equation 3.4 is greater than the critical value

for χ^2 with a probability, $\alpha \leq 0.05$. The critical value for χ^2 with 1 degree of freedom at $\alpha = 0.05$ is 3.841 (Hoel and Jessen 1982, 594). Similar tables and calculations of χ^2 using the aircraft and location specific subcategories determine if the entire population experiences the same difference or if it is aircraft or location specific.

Some may argue that the research should perform a Yates correction for continuity on a 2x2 contingency table with relatively low sample size. However, as Glass and Hopkins (1996, 335) point out, the Yates correction is not only unnecessary, but causes the already conservative values for α to be even more conservative. Therefore, this research does not apply the Yates correction for continuity.

However, for sets that equation 3.4 yields very small expected values, the research used an alternate method to test the null hypothesis. Because the χ^2 approximates the binomial distribution, the χ^2 test of association should not be applied when any of the expected numbers from the contingency table calculated from equation 3.4 is less than five (Edwards 1973, 139). For a 2x2 contingency table with any expected cell numbers less than five, this research applies a Fisher Exact Probability Test to determine the probability there is no association between the variables (Edwards 1973, 139-140). The calculation for the Fisher Exact Probability Test is quite lengthy and beyond the scope of this chapter. This research utilized an on-line applet to calculate the two-tailed Fisher Exact Probability (Lowry 2008) and rejected the null hypothesis if the two-tailed probability calculated by the Fisher Exact Probability Test is less than 5 percent.

To answer the subsequent research questions identified in chapter 1 this research used the following procedures.

Subsequent Research Question 1

Can the difference in high and low attrition categories meeting the sortie contract be attributed to over scheduling of the aircraft or from masking a unit capability shortfall?

As discussed in chapter 1, if the units were over scheduling aircraft and experiencing the “wrath of the scheduling death spiral”, months with low attrition rates (and therefore a lower scheduled UTE rate) should meet the sortie contract more often than months with a high attrition rate. Conversely, if the units were masking capability shortfalls with excessive attrition, months with high attrition rates should meet the sortie contract more often than months with low attrition rates. If the χ^2 test identifies a statistically significant difference between months with high scheduled attrition and months with low scheduled attrition, the descriptive statistics can determine if a preponderance of the sets indicate higher or lower attrition rates lead to a higher probability of meeting the sortie contract.

Subsequent Research Question 2

Do all of the different types of bombers experience the same statistically significant difference between months with high and low scheduled attrition with respect to the percent of months that each meets the sortie contract?

The purpose of this question was to determine if, for some unidentified reason, one type of aircraft performs better than another. This helped to identify which failure mode, if any, was occurring with different types of aircraft. Knowing which failure mode was occurring made it possible to provide a precise recommendation rather than just a general recommendation for the entire fleet.

To answer this question, the research used the same methodology applied to the primary research question. In this case, the population indicated in the research and null hypothesis was not the entire bomber fleet, but each type of bomber tested independently. All other methods outlined in chapter 3 were the same.

Subsequent Research Question 3

Does each of the MOBs experience the same statistically significant difference between months with high and low scheduled attrition with respect to the percent of months that each meets the sortie contract?

Similar to question 2, the purpose of this question was to determine if different MOBs were experiencing different failure modes. It is quite possible that attrition-scheduling techniques cause one MOB to over schedule their aircraft while another is masking unit capability shortfalls.

The research applied the analysis procedures for question 2 to questions 3. In contract to question 2, the analysis focused on each MOB independently.

Subsequent Research Question 4

Is there a better scheduling framework that can increase the probability of meeting the monthly contract?

This question was qualitative in nature, so there was no statistical test able to provide a definitive answer. However, to the extent that the data supported the research hypothesis, the research developed a new monthly scheduling framework without using historical attrition. Then the lexicographic goal-programming model introduced in

chapter 2 was used to evaluate how well the new scheduling framework performed when faced with a disruption.

Quality Considerations

A certain amount of caution needs to be exercised when interpreting the results of cause-comparative research models. Since the research did not individually manipulate variables and compare them to a control group, there was no clear approach to establish cause-effect relationships with a great degree of confidence (Gay 1996, 328). There is always a possibility that an additional, uncontrolled variable is responsible for an apparent cause-effect relationship between the independent and dependant variables. However, if the research collects and analyzes data correctly, a causal-comparative method can obtain results that make the cause-effect relationship plausible (Westmeyer 1994, 54).

Another consideration is the accuracy of the historical data maintained by P&S and in CAMS. One of the assumptions identified in chapter 1 was that each unit is followed the existing regulations and recorded data correctly. If one base is deviating from the regulations, those aircraft may incorrectly show differences in meeting the sortie contract due to flawed data. Sub-grouping the participant data by base helped to identify differences in unit's data quality.

Conclusion

To summarize the research methodology, this research used causal-comparative methods to test the null hypothesis. A nominal scale was applied to classify data into distinct categories. Control measures were established to mitigate the influence of

extraneous variables. Finally, a chi-squared test of association was used to test the difference among proportions between categories. In the case when one of the expected values in the contingency table was less than five, the research employed the Fisher Exact Probability Test. The next chapter presents the results of analysis of the data obtained from the research methods described above and provides findings related to the research questions.

CHAPTER 4

ANALYSIS

This chapter presents results of data analysis and addresses any quality considerations that may have affected the findings. Section 1 lists the descriptive statistics outlined in chapter 3 and includes a brief discussion of their significance. Then, section 2 answers the primary research question by analyzing the null hypothesis test. Finally, section 3 addresses the subsequent research questions identified in chapter 1.

Descriptive Statistics

Table 3 summarizes the eight descriptive statistics described in chapter 3. The table includes the descriptive statistics on the left side, broken down for Minot AFB (MT), Barksdale AFB (LA), Ellsworth AFB (EL), Dyess AFB (DY), and Whiteman AFB (WM). Additionally, the table shows the descriptive statistic for the B-2s, B-52, B-1s and the entire bomber fleet.

Table 3. Descriptive Statistics

	MT	*LA*	*EL*	*DY*	*WM/B-2*	*B-52s*	*B-1s*	*All*
Number of months	*20*	*24*	*24*	*24*	*10*	*44*	*48*	*102*
Overall attrition rate	*7.8%*	*12.0%*	*12.0%*	*12.2%*	*18.3%*	*10.9%*	*12.1%*	*12.1%*
Median attrition	*6.2%*	*12.1%*	*11.4%*	*13.4%*	*16.2%*	*11.4%*	*12.2%*	*11.9%*
Attrition Range								
Min	*0.0%*	*5.1%*	*7.6%*	*0.0%*	*12.5%*	*0.0%*	*0.0%*	*0.0%*
Max	*19.4%*	*16.9%*	*20.2%*	*16.7%*	*26.6%*	*19.4%*	*20.2%*	*26.6%*
% months met goal								
overall	*40.0%*	*29.2%*	*12.5%*	*54.2%*	*60.0%*	*34.1%*	*33.3%*	*36.3%*
with low attrition	*10.0%*	*8.3%*	*8.3%*	*33.3%*	*20.0%*	*22.7%*	*12.5%*	*15.7%*
with high attrtion	*70.0%*	*50.0%*	*16.7%*	*75.0%*	*100.0%*	*45.5%*	*54.2%*	*56.9%*

Source: Created by author.

From table 3, the scheduled attrition rate ranged from 0 percent at Minot AFB and Dyess AFB to over 26 percent at Whiteman AFB. The median attrition rate for the fleet was 11.9 percent. Minot AFB scheduled to lowest overall attrition at 7.8 percent, while Whiteman AFB scheduled to highest at 18.3 percent. Whiteman AFB met the sortie contact 60 percent of the time, higher than any other aircraft type or MOB. Ellsworth AFB met the sortie contract least often, with 12.5 percent of the months.

Figure 2 represent the overall rate that the bomber fleet met the monthly contract.

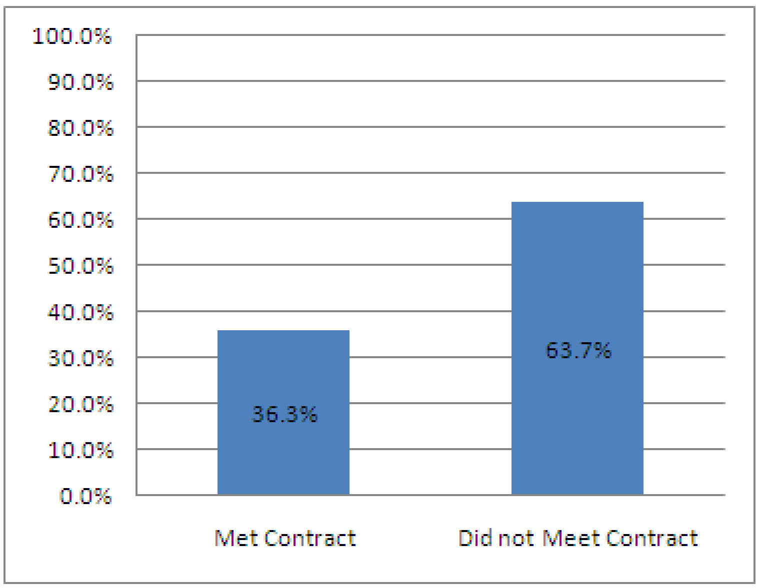

Figure 2. Rate Bomber Units Met Monthly Contract
Source: Created by author.

The USAF bomber fleet only met the monthly contract in 36.3 percent of the months evaluated. Failing to meet the sortie contract nearly two out of every three months has a negative impact on aircrew training and readiness. This figure alone shows

that there are issues across the bomber fleet that is preventing them from meeting their sortie contract consistently.

Figure 3 displays the frequency of "high" scheduled attrition by month through the year.

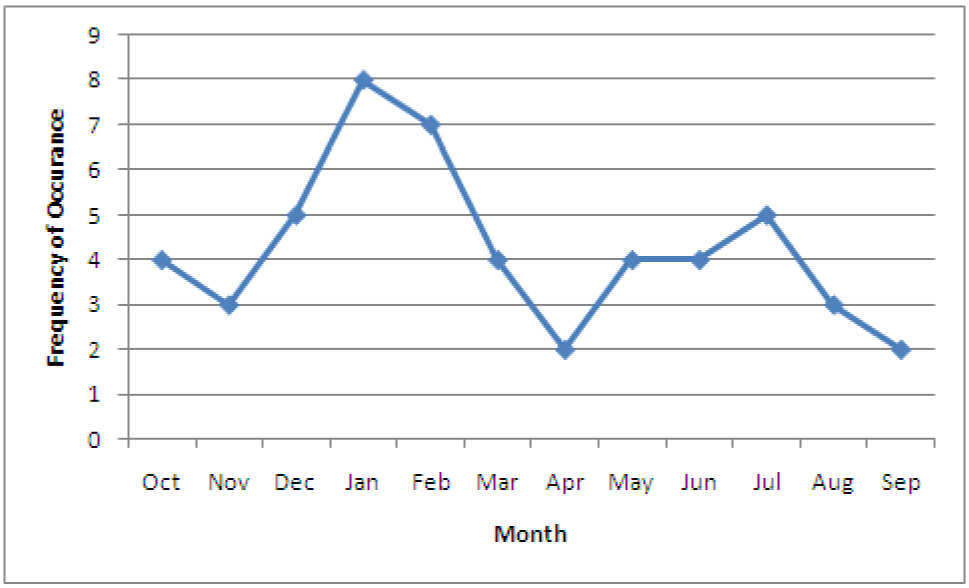

Figure 3. Frequency of "High" Scheduled Attrition by Month
Source: Created by author.

The research classified the month of January as "high" attrition eight times, while April and September were only classified as "high" attrition two times each. This difference is due to the impact of historical weather attrition. The winter months had more occurrences of "high" attrition than any other season.

Figure 4 displays the number of times the research classified each month as "high" attrition and the number of time each month met the sortie contract.

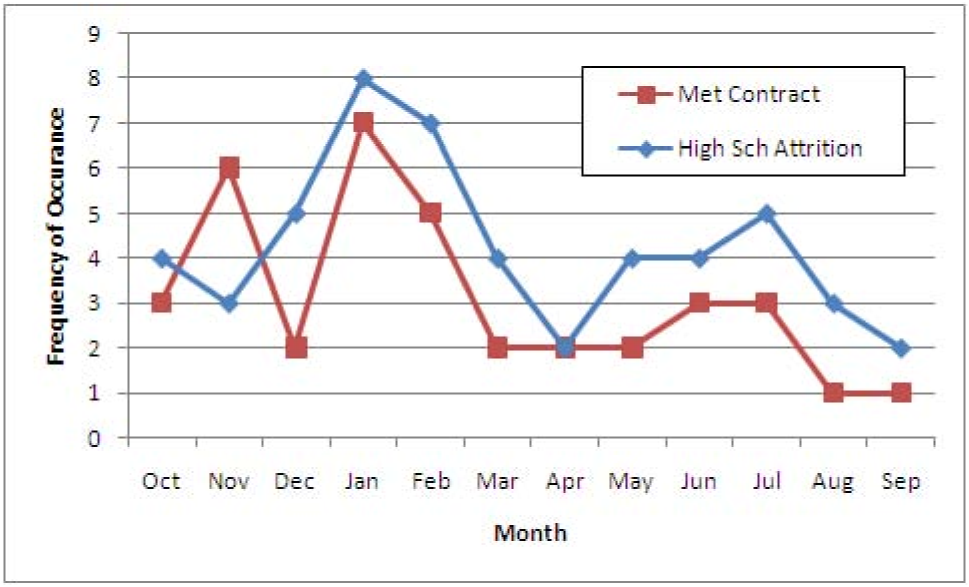

Figure 4. Frequency of Meeting the Sortie Contract Compared to “High” Scheduled Attrition by Month
Source: Created by author.

There appears to be a correlation between meeting the sortie contract and number of months with “high” scheduled attrition.

If using historical attrition is an effective way to meet the sortie contract, the frequency that each month meets the sortie contract should not change with respect to the frequency of “high” scheduled attrition for that month. Figure 4 shows that the month with the most occurrences of “high” scheduled attrition, January, also met the sortie contract seven times, more than any other month. Additionally, September, one of the months with the least occurrences of “high” scheduled attrition, only met the sortie contract once. The months of November and December do not appear to follow the same trend. The data classified November as “high” attrition only three times, but it met the sortie contract six times. Then the data classified December as “high” attrition five times, but it only meets the sortie contract twice. There are many of reasons that can explain the

apparent nonconformity of these two months including effects of the holiday season and manpower availability. However, the most probable cause is a result of a random distribution and a relatively small sample size. Although the research could not make any inferences about the population from figure 4 does, it appears that units meet the sortie contract more often in months with "high" scheduled attrition. To determine if there is a statistically significant relationship, the research tested the primary research question and research hypothesis.

Primary Research Question

Primary research question from chapter 1: Is the current USAF scheduling technique of using a five-year historical attrition rate an effective way to ensure the bomb wings' consistently meet their monthly sortie contracts?

To answer this question, the research used the following research hypothesis: USAF bomber fleet experience a statistically significant difference between months with high and low scheduled attrition with respect to the percent of months that each meets the sortie contract. The research tested the corresponding null hypothesis, H_o: USAF bomber fleet does not experience a statistically significant difference between months with high and low scheduled maintenance attrition with respect to the percent of months that each meets the sortie contract.

Table 4 represents the 2x2 contingency table for the entire bomber fleet.

Table 4. Contingency Table for All Bombers

Met Sortie Contract, r	***Scheduled Attrition Category, c*** *Low*	*High*	***Row Totals***
Yes	*8* *15.7%*	*29* *56.9%*	*37* *36.3%*
No	*43* *84.3%*	*22* *43.1%*	*65* *63.7%*
Column Totals	*51*	*51*	*102*

Source: Created by author.

Table 4 indicates that the bomber fleet met the sortie contract in 37 of the 102 months included in the sample, and did not meet the contract in 65 of the months. Of the 37 months that the bombers met the contract, 29 of them were in months with high scheduled attrition and 8 of them were in months with low scheduled attrition. Of the 65 months that they did not meet the contract, 22 of them were in months with high scheduled attrition and 43 of them were in months with low scheduled attrition. If the null hypothesis is true, there should be no relationship between the independent variable, the classification of scheduled attrition, and the dependant variable, percent of months that met the contract. However, table 4 shows that in months with low scheduled attrition, the units met the contract 15.7 percent of the time compared to 56.9 percent of the months with high scheduled attrition. The χ^2 test of association indicated there is a statistically significant relationship between the variables and rejected the null hypothesis (p=0.00002). The research found that using historical attrition is not an effective way to ensure bomb wings' are consistently meeting their monthly sortie contracts.

Subsequent Research Question 1

Can the difference in high and low attrition categories meeting the sortie contract be attributed to over scheduling of the aircraft or from masking a unit capability shortfall?

The χ^2 test for association established a statistically significant relationship between scheduled attrition rate and the probability of meeting the sortie contract. However, the χ^2 test for association is inherently non-directional, making it impossible to determine with an exact level of confidence if the difference is from over scheduling or from masking a unit capability shortfall. As discussed in chapter 1, if the units were over scheduling aircraft, they should meet the sortie contact more often in months with low scheduled attrition. Conversely, if the units were masking capability shortfalls with excessive attrition, they should meet their contract more often in months with high scheduled attrition rate. The data from table 4 shows that the bomber units met the contract in 56.9 percent of the months with high scheduled attrition compared to just 15.7 percent of the months with low scheduled attrition. Therefore, the data supports attributing the cause of the difference between high and low attrition categories meeting the sortie contract to the masking of unit capabilities shortfalls.

Subsequent Research Question 2

Do all of the different types of bombers experience a statistically significant difference between months with high and low scheduled attrition with respect to the percent of months that each meets the sortie contract?

As presented in chapter 3, the research tested this question with the same research methodology as the primary research questions and null hypothesis. Table 5 represents the 2x2 contingency table for the B-1 fleet.

Table 5. Contingency Table for All B-1s

Met Sortie Contract, r	*Low*	*High*	***Row Totals***
	Maintenance Attrition Category, c		
Yes	*3* *12.5%*	*13* *54.2%*	*16* *33.3%*
No	*21* *87.5%*	*11* *45.8%*	*32* *66.7%*
Column Totals	*24*	*24*	*48*

Source: Created by author.

Table 5 indicates that the B-1 fleet met the sortie contract in 16 of the 48 months included in the sample, and did not meet the contract in 32 of the months. Of the 16 months that the B-1s met the contract, 13 of them were in months with high scheduled attrition and 3 of them were in months with low scheduled attrition. Of the 32 months that they did not meet the contract, 11 of them were in months with high scheduled attrition and 21 of them were in months with low scheduled attrition. Table 5 shows that in months with low scheduled attrition, the B-1 units met the contract 12.5 percent of the time compared to 54.2 percent of the months with high scheduled attrition. The χ^2 test of association indicates the B-1 units display a statistically significant relationship between the variables (p=0.0022). The research found that B-1 units experience a statistically significant difference between months with high and low scheduled attrition with respect to the percent of months that each meets the sortie contract as the entire bomber fleet.

Table 6 represents the 2x2 contingency table for the B-52 fleet.

Table 6. Contingency Table for All B-52s

Met Sortie Contract, *r*	*Maintenance Attrition Category, c* Low	High	**Row Totals**
Yes	*5* *22.7%*	*10* *45.5%*	*15* *34.1%*
No	*17* *77.3%*	*12* *54.5%*	*29* *65.9%*
Column Totals	*22*	*22*	*44*

Source: Created by author.

Table 6 indicates that the B-52 fleet met the sortie contract in 15 of the 44 months included in the sample, and did not meet the contract in 29 of the months. Of the 15 months that the B-52s met the contract, 10 of them were in months with high scheduled attrition and 5 of them were in months with low scheduled attrition. Of the 29 months that they did not meet the contract, 12 of them were in months with high scheduled attrition and 17 of them were in months with low scheduled attrition. Table 6 shows that in months with low scheduled attrition, the B-52 units met the contract 22.7 percent of the time compared to 45.5 percent of the months with high scheduled attrition. The χ^2 test of association indicates the B-52 units do not display a statistically significant relationship between the variables (p=0.1118). The research found that B-52 units do not experience a statistically significant difference between months with high and low scheduled attrition with respect to the percent of months that each meets the sortie contract as the entire bomber fleet.

Table 7 represents the 2x2 contingency table for the B-2 fleet.

Table 7. Contingency Table for All B-2s and Whiteman AFB

Met Sortie Contract, r	***Maintenance Attrition Category, c*** *Low*	*High*	***Row Totals***
Yes	*1* *20.0%*	*5* *100%*	*6* *60.0%*
No	*4* *80.0%*	*0* *0.0%*	*4* *40.0%*
Column Totals	*5*	*5*	*10*

Source: Created by author.

Table 7 indicates that the B-2 fleet met the sortie contract in 6 of the 10 months included in the sample, and did not meet the contract in 4 of the months. Of the six months that the B-2s met the contract, five of them were in months with high scheduled attrition and one of them was in a month with low scheduled attrition. Of the four months that they did not meet the contract, all of them were in months with low scheduled attrition. After applying equation 3.4 to table 7, it is clear that each cell has an expected value of less than five. In accordance with chapter 3, the research used the Fisher Exact Probability Test to determine the probability of this distribution occurring by chance with no relationship between the attrition category and the ability to meet the sortie contract. The Fisher Exact Probability Test indicated the B-2 units displayed a statistically significant relationship between the variables (p=0.0476). The research found that B-2 units experience a statistically significant difference between months with high and low scheduled attrition with respect to the percent of months that each meets the sortie contract as the entire bomber fleet.

Since Whiteman AFB is the only MOB that flies the B-2, the results from table 7 are used to represent the B-2 fleet and Whiteman.

To summarize subsequent research question 2, not all types of bomber experienced a statistically significant difference between months with high and low scheduled attrition with respect to the percent of months that each meets the sortie contract. Specifically, the B-1s and B-2 displayed a statistically significant difference while the B-52s did not. The B-52s are not meeting the sortie contract more consistently than the other bombers. However, the research cannot determine if the B-52s perform better with high or low attrition.

Subsequent Research Question 3

Does each MOB experience a statistically significant difference between months with high and low scheduled attrition with respect to the percent of months that each meets the sortie contract?

As presented in chapter 3, the research tested this question with the same research methodology as the primary research questions and null hypothesis. Table 8 represents the 2x2 contingency table for the B-52 wing at Minot AFB.

Table 8. Contingency Table for Minot AFB

	Maintenance Attrition Category, c		
Met Sortie Contract, r	*Low*	*High*	***Row Totals***
Yes	*1* *10.0%*	*7* *70.0%*	*8* *40.0%*
No	*9* *90.0%*	*3* *30.0%*	*12* *60.0%*
Column Totals	*10*	*10*	*20*

Source: Created by author.

Table 8 indicates that the B-52s at Minot AFB met the sortie contract in eight of the 20 months included in the sample, and did not meet the contract in 12 of the months. Of the eight months that the B-52s at Minot AFB met the contract, seven of them were in months with high scheduled attrition and one of them was in a month with low scheduled attrition. Of the 12 months that they did not meet the contract, 3 of them were in months with high scheduled attrition and 9 of them were in months with low scheduled attrition. After applying equation 3.4 to table 8, it is clear that the cells in the "yes" row and "low" and "high" columns have an expected value of less than five. In accordance with chapter 3, the research used the Fisher Exact Probability Test to determine the probability of this distribution occurring by chance with no relationship between the attrition category and the ability to meet the sortie contract. The Fisher Exact Probability Test indicates the B-52s at Minot AFB display a statistically significant relationship between the variables (p=0.0198). The research found that B-52s at Minot AFB experience a statistically significant difference between months with high and low scheduled attrition with respect to the percent of months that each meets the sortie contract as the entire bomber fleet.

Table 9 represents the 2x2 contingency table for the B-52 wing at Barksdale AFB.

Table 9. Contingency Table for Barksdale AFB

Met Sortie Contract, r	***Maintenance Attrition Category, c*** *Low*	*High*	***Row Totals***
Yes	*1* *8.3%*	*6* *50.0%*	*7* *29.2%*
No	*11* *91.7%*	*6* *50.0%*	*17* *70.8%*
Column Totals	*12*	*12*	*24*

Source: Created by author.

Table 9 indicates that the B-52s at Barksdale AFB met the sortie contract in 7 of the 24 months included in the sample, and did not meet the contract in 17 of the months. Of the seven months that the B-52s at Barksdale AFB met the contract, six of them were in months with high scheduled attrition and one of them was in a month with low scheduled attrition. Of the 17 months that they did not meet the contract, 6 of them were in months with high scheduled attrition and 11 of them were in months with low scheduled attrition. After applying equation 3.4 to table 9, it is clear that both the "yes-low" cell and "yes-high" cell have an expected value of less than five. In accordance with chapter 3, the research used the Fisher Exact Probability Test to determine the probability of this distribution occurring by chance with no relationship between the attrition category and the ability to meet the sortie contract. The Fisher Exact Probability Test indicates the B-52s at Barksdale AFB do not display a statistically significant relationship between the variables (p=0.0686). The research found that B-52s at Barksdale AFB do not experience a statistically significant difference between months

with high and low scheduled attrition with respect to the percent of months that each meets the sortie contract as the entire bomber fleet.

The overall percentage of months that met the sortie contract for the B-52s at Barksdale AFB is similar to the entire bomber fleet and the B-52 fleet. However, since the data failed to reject the null hypothesis in this case, it cannot be determine if the Barksdale B-52s performs better with high or low attrition. Statistically, they are the same.

Table 10 represents the 2x2 contingency table for the B-1 wing at Ellsworth AFB.

Table 10. Contingency Table for Ellsworth AFB

	Maintenance Attrition Category, c		
Met Sortie Contract, r	*Low*	*High*	***Row Totals***
Yes	*1* *8.3%*	*2* *16.7%*	*3* *12.5%*
No	*11* *91.7%*	*10* *83.3%*	*21* *87.5%*
Column Totals	*12*	*12*	*24*

Source: Created by author.

Table 10 indicates that the B-1s at Ellsworth AFB met the sortie contract in 3 of the 24 months included in the sample, and did not meet the contract in 21 of the months. Of the three months that the B-1s at Ellsworth AFB met the contract, two of them were in months with high scheduled attrition and one of them was in a month with low scheduled attrition. Of the 21 months that they did not meet the contract, 10 of them were in months with high scheduled attrition and 11 of them were in months with low scheduled

attrition. After applying equation 3.4 to table 10, it is clear that both the “yes-low” cell and “yes-high” cell have an expected value of less than five. In accordance with chapter 3, the research used the Fisher Exact Probability Test to determine the probability of this distribution occurring by chance with no relationship between the attrition category and the ability to meet the sortie contract. The Fisher Exact Probability Test indicates the B-1s at Ellsworth AFB do not display a statistically significant relationship between the variables (p=0.9999). The research found that B-1s at Ellsworth AFB do not experience a statistically significant difference between months with high and low scheduled attrition with respect to the percent of months that each meets the sortie contract as the entire bomber fleet.

The data in table 10 indicates that Ellsworth only met the sortie contract 3 out of 24 months. Even though the data fails to reject the null hypothesis, it is clear that Ellsworth is not consistently meeting the sortie contract. However, this research cannot attribute the reason for not meeting the contract to the magnitude of their scheduled attrition rate.

Table 11 represents the 2x2 contingency table for the B-1 wing at Dyess AFB.

Table 11. Contingency Table for Dyess AFB

Met Sortie Contract, r	***Maintenance Attrition Category, c*** *Low*	*High*	***Row Totals***
Yes	*4* *33.3%*	*9* *75.0%*	*13* *54.2%*
No	*8* *66.7%*	*3* *25.0%*	*11* *45.8%*
Column Totals	*12*	*12*	*24*

Source: Created by author.

Table 11 indicates that the B-1s at Dyess AFB met the sortie contract in 13 of the 24 months included in the sample, and did not meet the contract in 11 of the months. Of the 13 months that the B-1s at Dyess AFB met the contract, 9 of them were in months with high scheduled attrition and 4 of them were in months with low scheduled attrition. Of the 11 months that they did not meet the contract, 3 of them were in months with high scheduled attrition and 8 of them were in months with low scheduled attrition. Table 11 shows that in months with low scheduled attrition, the B-1s at Dyess AFB met the contract 33.3 percent of the time compared to 75 percent of the months with high scheduled attrition. The χ^2 test of association indicates the B-1s at Dyess AFB display a statistically significant relationship between the variables (p=0.0405). The research found that B-1s at Dyess AFB experience a statistically significant difference between months with high and low scheduled attrition with respect to the percent of months that each meets the sortie contract as the entire bomber fleet.

The last MOB to analyze is Whiteman AFB. However, since Whiteman is the only MOB to operate the B-2, the results from contingency table 7 is valid here. The data

indicates that Whiteman AFB experiences a statistically significant difference between months with high and low scheduled attrition with respect to the percent of months that each meets the sortie contract as the entire USAF bomber fleet.

To summarize subsequent research question 3, not all MOBs experienced a statistically significant difference between months with high and low scheduled attrition with respect to the percent of months that each meets the sortie contract. Specifically, the Minot AFB, Whiteman AFB, and Dyess AFB displayed a statistically significant difference while the Ellsworth AFB and Barksdale AFB did not. Ellsworth AFB and Barksdale AFB are not meeting the sortie contract more consistently than the other bases, however, the research cannot determine if they perform better with high or low attrition.

Subsequent Research Question 4

Is there a better scheduling framework that can increase the probability of meeting the monthly contract?

As discussed in chapter 2, the current USAF attrition scheduling techniques use historical loses to predict future loses in an effort to ensure units meet their sortie contract. As data in figure 2 indicates, USAF bomber units are not consistently meeting their sortie contract. Additionally, the data supported the research hypothesis that USAF bomber fleet experience a statistically significant difference between months with high and low scheduled attrition with respect to the percent of months that each meets the sortie contract. The following section introduces two possible frameworks, which do not rely on historical attrition, but can increase the probability of meeting the monthly contract if applied in the correct situation.

To develop and analyze new frameworks, the research recreates a notional monthly schedule with 20 operations and maintenance (O&M) days, a sortie contract of 100 sorties, and a five-year historical attrition of 11.9 percent. For the purpose of this analysis, consider $f(x)$ as the monthly schedule required to meet the sortie contract. To determine how well each framework responds to a disruption, the research applies a lexicographic goal-programming model presented in chapter 2.

The current attrition framework requires the unit to schedule 114 sorties to meet the 100-sortie contract, averaging 5.7 sorties scheduled per day. However, the goal-programming model cannot analyze this framework. Recall from chapter 2 that x^o is the optimal solution to $f(x)$. Attrition scheduling attempts to account for expected losses by adding additional scheduled sorties. If extra attrition sorties are pre-loaded into the monthly schedule, then x^o is not the optimal solution to $f(x)$. Consider the following two frameworks that do not include historical sortie attrition.

Evenly Distributed Framework

Using an evenly distributed framework, the unit scheduler evenly distributes the 100 required sorties among the 20 O&M days, averaging five sorties scheduled per day. This reduces the scheduled UTE rate resulting in more down time for maintenance, which may increase the reliability of the aircraft. If a disruption occurs, the schedulers could use the lexicographic goal-programming model represented in equation 4.1 to recover.

$$\begin{aligned} &\text{Min } Lex\ P1{:}\,h(\beta^+,\beta^-) \quad P2{:}\ \min g(\mathrm{a}^+,\mathrm{a}^-) \quad P3{:}\ \hat{f}(x) \\ &\text{subject to } x+\beta^+-\beta^- \in \hat{X} \\ &\qquad\qquad x+a^+-a^- = x^o \\ &\qquad\qquad a^+,a^-,\beta^+,\beta^- \geq 0 \end{aligned} \tag{4.1}$$

The scheduler's first priority is to minimize the cost of not finding a solution in the new feasible set, $h(\beta^{+}, \beta^{-})$. In other word, if it is not even possible to make-up the lost training, find a solution that minimizes the training lost. An example of not finding a solution in the new feasible set could be a situation where the disruption occurred on a day where a unique type of mission was scheduled. Some high-use bombing ranges' schedules fill-up six months out. If the disruption caused a sortie heading to a high-use bombing range to cancel, there may not be any more opportunities to recover the lost training during that month. Even though no solution exists that can recover the lost training opportunity, schedulers should minimize the cost to the overall aircrew readiness by re-prioritizing missions and aircrew to the extent allowed by the new feasible set.

If the schedulers can identify multiple solutions in the feasible set, the next priority is to minimize the deviation cost, $g(\mathrm{a}^{+}, \mathrm{a}^{-})$. In other words, find a solution that is as close to the original schedule as possible. The deviation cost is more than just the amount of money required to implement the new solution. Is also includes the amount of man hours required, the cost of deferring maintenance to a later date and the cost of the increased risk to the rest of the monthly schedule. For example, if a local training sortie cancels on a Monday, a new solution in the feasible set may be to fly the same sortie later the same week. Since the evenly distributed framework reduced the scheduled UTE rate, it is possible that additional aircraft are available to fill the need. However, the schedulers need to minimize the cost of adding the sortie, by selecting solutions that reduce the impact on the available labor force, scheduled maintenance and reduces the risk to the rest of the monthly flying schedule.

If the schedulers can identify multiple solutions in the feasible set that can minimize the deviation cost, the next priority should be to minimize the objective function, $\hat{f}(x)$. To minimize the objective function, schedulers seek to combine training opportunities and reduce the number of sorties required. Additionally, the schedulers should seek to minimize the new solution's impact on the length of flying day, down time between launches and the daily turn pattern. A minimized objective function represents the most efficient means of meeting all of the training goals.

The largest benefit from using an evenly distributed framework is the reduction in scheduled UTE rate and minimized impact to external customers. An evenly distributed framework only schedules the required number air refueling, bomb ranges, formations, etc, without adding additional requirements that the unit plans on canceling. This is the best option for units that are currently meeting the monthly sortie contract more often with low scheduled attrition.

Front Loaded Framework

In a front loaded framework, the schedulers plan all 100 required sorties in the first 18 O&M days of the month, averaging 5.6 sorties scheduled per day with no sorties scheduled on the last two days of the month. The scheduled UTE rate is similar to the attrition framework, but there are no sorties scheduled on the last two flying days of the month. Schedulers can use these days as "make-up" days if disruptions occur earlier in the month. If a disruption occurs, the schedulers could use the lexicographic goal-programming model represented in equation 4.2 to recover.

$$\begin{aligned} &\text{Min } \textit{Lex P1:} h(\beta^+, \beta^-) \quad \textit{P2:} \hat{f}(x) \quad \textit{P3:} \min g(\mathrm{a}^+, \mathrm{a}^-) \\ &\text{subject to } x + \beta^+ - \beta^- \in \hat{X} \\ &\qquad x + a^+ - a^- = x^o \\ &\qquad a^+, a^-, \beta^+, \beta^- \geq 0 \end{aligned} \tag{4.2}$$

Similar to the evenly distributed framework, the scheduler's first priority is to minimize the cost of not finding a solution in the new feasible set, $h(\beta^+, \beta^-)$. If the disruption caused a sortie scheduled for a unique mission to cancel, there may not be any more opportunities to recover the lost training during that month. Even though no solution exists that can recover the lost training opportunity, schedulers should minimize the cost to the overall aircrew readiness by re-prioritizing missions and aircrew to the extent allowed by the new feasible set.

If the schedulers identify multiple solutions in the feasible set, the next priority is to minimize the objective function, $\hat{f}(x)$. The front loaded framework easily minimizes the objective function. With no sorties scheduled on the last two days of the month, these days are great locations to add make-up sorties to account for losses earlier in the month. To minimize the objective function, schedulers should schedule the minimum number of sorties on the minimum number of days. For example, if two sorties canceled earlier in the month, one possible solution to minimize the objective function is to schedule them both on the same make-up day at the end of the month. This approach minimizes the objective function more than scheduling one make-up sortie on each make-up day at the end of the month.

If the schedulers can identify multiple solutions in the feasible set and minimize the objective function, the next priority is to minimize the deviation cost, $g(\mathrm{a}^+, \mathrm{a}^-)$. Since the front-loaded framework has a higher scheduled UTE rate, it is unlikely that

additional aircraft are available to fill the need. However, there are two days at the end of the flying month that schedulers can add sorties to while attempting to minimize the cost.

The greatest benefit from the front loaded framework is the pre-programmed recovery days. This framework is the best option for units that meet the sortie contract more often with high scheduled attrition, such as Minot AFB, Whiteman AFB, and Dyess AFB. The goal of the front loaded framework is not to expect sorties to cancel and make them up later, but to focus management's attention on the reason for the canceled sorties, and ideally correct the problem. If a unit is able to correct the root causes for the lost sorties, there will be few if any sorties canceled during the month. Management can use the last two O&M days of the month as maintenance down days and training days. More down time for maintenance may increase the reliability of the aircraft and the probability of making the sortie contract the following month.

However, there is a downside to the front-loaded framework. Just because there are two days at the end of the month to add sorties, does not mean that units have the external customer support for those days. Operations schedulers negotiate air-refueling schedules at least 3 months in advance, and bomb ranges fill up at least a month prior. One possible solution is for the operations schedulers to book air refueling and bomb ranges through the end of the month to support a 5.6 sortie UTE rate. Then if there is a disruption early in the month, the external customer support is available on the last two make-up days. If there is not a disruption early in the month, the schedulers can cancel the external support for the last two O&M days. On the surface, this may appear inefficient and wasteful with respect to the external customers' support. However, this approach is more efficient than the current attrition scheduling process. The current

process plans on a set number of sorties canceling each month, but cannot identify which sorties will cancel. The front loaded schedule identifies the last two O&M days as the highest probability of cancelation. Either way, the units schedule the same amount of external customer support, but the front-loaded framework can identify which sorties are most likely to cancel. This could have second order effects for the external customers, and allow them to plan alternate activities if the bomber unit cancels the requirement for the last two O&M days of the month.

The evenly distributed and front loaded frameworks are just two examples of how disruption management scheduling techniques can increase the effectiveness and efficiency of executing a monthly schedule. The difference in efficiency and effectiveness is apparent when comparing attrition scheduling techniques to disruption management techniques.

Attrition scheduling starts with a sub-optimized solution, and attempts to account for predicted losses. If the losses are less than predicted, management deems the schedule a success but nobody focuses on why the sorties canceled. Although ACCI 21-165 states, "a sortie lost will normally be flown in the same month the loss occurred" (United States Air Force 2008, 46), the increased UTE rate required by attrition scheduling and the absence of a pre-planned make-up day make it difficult to fly the sortie in the same month it was lost. If the losses exceed the prediction, there is no mechanism to make adjustments during execution; it just increases the attrition rate next year.

Disruption management scheduling starts with an optimized solution and assumes every sortie will fly. When a disruption occurs, or a sortie cancels, two things occur. First, since the canceled sortie threatens the success of the monthly schedule, mangers

focus their attention is on why the sortie canceled. Second, managers at all levels apply a pre-determined set of priorities to recover from the disruption during the month of execution. The focus on why sorties cancel can increase the efficiency of the maintenance unit, and the ability to make adjustments during the month of execution can increase the effectiveness when compared to attrition scheduling techniques.

Conclusion

This chapter presented the data obtained from the methodology identified in chapter 3, tested the null hypothesis, and answered the primary and subsequent research questions. Key findings include:

1. Historical attrition is not an effective way to ensure bomb wings' are consistently meeting their monthly sortie contracts.

2. The difference between high and low attrition categories meeting the sortie contract is most likely caused by the attrition rate masking unit capability shortfalls.

3. Not all types of bomber experienced a statistically significant difference between months with high and low scheduled attrition with respect to the percent of months that each meets the sortie contract. Specifically, the B-1s and B-2 displayed a statistically significant difference while the B-52s did not.

4. Not all MOBs experienced a statistically significant difference between months with high and low scheduled attrition with respect to the percent of months that each meets the sortie contract. Specifically, the Minot AFB, Whiteman AFB and Dyess AFB displayed a statistically significant difference while the Ellsworth AFB and Barksdale AFB did not

5. Applying disruption management techniques to an optimized schedule can increase the efficiency of a unit while increasing the effectiveness of the monthly flying schedule.

Chapter 5 presents conclusions and recommendations drawn from these findings.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

Chapter 4 presented and analyzed results, answered the primary and subsequent research questions, and detailed a scheduling framework based on a lexicographic goal-programming model. Based on findings, this chapter identifies four conclusions, makes one recommendation for implementation and makes two recommendations for further research.

Conclusions

The first conclusion is very simple, but warrants discussion. Simply put, the USAF bomber fleet is not consistently meeting their monthly sortie contracts, regardless of attrition level. From the descriptive statistics presented in chapter 4, the bomber fleet successfully met their sortie contract in only 36.3 percent of the months included in this research. One of the assumptions made in chapter 1 was that schedulers designed the monthly contract to meet the flying squadron's monthly training requirement. If that assumption is valid, then it is plausible that only meeting the monthly sortie contract 36.3 percent of the time is negatively impacted aircrew training. Additionally, this problem is consistent across the entire bomber fleet. It is unlikely that the individual units have the resources, insight, or even the desire to implement organizational changes. Headquarters ACC needs to change to how bomber units plan for and execute monthly flying schedules, and make applicable changes to the ACCIs and doctrine.

The second conclusion is that using a five-year historical attrition, calculated on a monthly basis, to account for future loses is not an effective method to ensure bomber

units meet their monthly contract. On the surface, adding attrition sorties into the monthly contract to account for anticipated loses appears to be a logical and effective way to ensure the units meet the sortie contract. If attrition scheduling was an effective method to ensure the units meet their sortie contract, then the probability of meeting the monthly contract should be independent of the magnitude of the historic attrition. Months with low historical attrition should have the same probability of meeting the sortie contract as months with high historical attrition. However, as chapter 4 identified, there is a statistically significant relationship between the magnitude of the scheduled attrition and the probability of meeting the monthly sortie contract.

Upon closer investigation of the monthly attrition calculation, two problems appear that may help highlight the fundamental flaws of using monthly historical attrition to predict the future attrition. First, with the exception of weather attrition, there is no reason that attrition should vary month-to-month. For example, in January 2007, Ellsworth AFB canceled six sorties for a national day of mourning following the death of President Gerald Ford. In accordance with ACCI 21-165, the unit recorded the cause for the lost sorties as higher headquarters cancels. These six sorties represented 7.5 percent of the sorties scheduled for January 2007. Using current attrition scheduling techniques, for fiscal years 2008-2012 Ellsworth AFB is expecting an increased number of higher headquarters cancels in the month of January because a former president died during the month of January. Similarly, there is no reason that schedulers should expect monthly changes in supply cancels, operations cancels, maintenance cancels, and cancels due to exercises to follow the same monthly pattern from year-to-year. The second problem is that attrition is intended to account for losses outside of the unit's control (United States

Air Force 2008, 46). However, every sortie lost, even if the reason was within the unit's control, is included in the attrition rate calculation. This also helps explain the third conclusion.

The third, and possibly most important conclusion, is that the probability seems high that attrition rates are masking a unit capability shortfall. As identified in chapter 4, there is a statistically significant difference between months with high and low scheduled attrition with respect to meeting the sortie contract. Additionally, the bomber fleet met the sortie contract more often with high scheduled attrition than in months with low scheduled attrition. This indicates the existence of at least one limiting factor that is preventing the units from meeting the sortie contract without scheduling a significant amount of attrition. This limiting factor could be from the work force, availability of parts, poor training or lack of test equipment. By masking the limiting factor, attrition scheduling makes it possible to meet the sortie contract without drawing attention to the reason sorties were lost. Just because a unit lost 20 percent of its sorties for the past five years does not mean it is acceptable to cancel 20 percent in the future.

It is tempting to draw the conclusion that since units meet the sortie contract more often with high attrition, then units should increase their attrition even more to meet the sortie contract more often. While this approach may provide temporary results, this approach just covers the problem and diverts attention from the root cause of the canceled sorties.

The fourth conclusion is that the bomb wings can benefit from disruption management techniques. As discussed in chapter 4, attrition scheduling starts with a sub-optimized schedule and has no standardized mechanism to adjust the schedule during the

month of execution. Applying disruption management techniques to an optimized schedule can increase the efficiency of the units and increase the effectiveness of the month schedule.

Recommendations for Implementation

This research identified on recommendation for implementation. HQ ACC should change the instructions and doctrine to direct units to stop using historical attrition, with the exception of weather attrition, to predict future losses. Weather attrition follows a predictable pattern from month-to-month and is beyond the units' control. Therefore, bomb wings should still apply a small weather attrition factor based on historical data. The changes to the instructions should not dictate what type of scheduling framework each unit should apply. The instructions should direct units to start with an optimized schedule and have a pre-determine plan of action if a disruption occurs. Additionally, the AFTTPs should include non-regulatory guidance on which type of framework the units should apply based on their own situation. For example, if a unit is only meeting the sortie contract with inflated attrition rates, the frontloaded framework, or something like it, is the preferred scheduling framework.

Recommendations for Future Research

The research identified two recommendations for future research. First is to conduct additional research into the root cause of the canceled sorties. Even if HQ ACC does not implement the recommendation for implementation, management needs to identify and correct the unit capability shortfalls or the probability of meeting the sortie contract consistently will remain low. Related to this recommendation is the delimitation

the research identified in chapter 1; this research does not examine the impact of deployed operations on home station's ability to execute a monthly flying schedule. It is possible that bomb units have experienced a significant drop in their ability to generate home station sorties due to constant deployments and high operations tempo. Analyzing the impact of deployed operations was outside the scope of this research, but it may partially explain why bomb wings are only meeting their home station contract 36.3 percent of the time.

Second, since this research only studied the impact of historical attrition on USAF bomb wings, the results are not transferable to other units and types of aircraft. The final recommendation for future research is to perform the same analysis on other units and types of aircraft to determine if historical attrition is having the same impact on their ability to meet the monthly contract.

Conclusion

This research analyzed nearly two years of data across all USAF bomb wings to determine if using historical attrition rates are an effective method to predict future losses and ensure units meet their monthly contract consistently. The statistical analysis was convincing that the bomber fleet is more likely to meet the sortie contract in month with high scheduled attrition than in a month with low scheduled attrition. Additionally, the research introduced the application of disruption management as a method to manage a flying schedule built with no scheduled attrition to increase the units' efficiency and the schedules' effectiveness. Finally, the research made a recommendation to stop using attrition scheduling in USAF bomb wings, and made two recommendations for future

research to identify what capability shortfalls are masked by attrition and to perform similar research on other types of aircraft.

GLOSSARY

Attrition: Losses expected based on historical data. Sorties added by maintenance scheduling to a unit's sortie contract to allow for expected losses due to maintenance, operations, supply, air traffic control, sympathy, higher headquarters, other cancellations, and weather cancellations. If attrition is less or more than planned, operations and maintenance schedulers should adjust the schedule to prevent overextending maintenance and/or to stay within the unit's sortie flying-hour program. Attrition sorties are not substitutes for capability shortfalls; they are additive to the contract to ensure mission goals are met. The operations and maintenance units will normally attempt to make up sorties in the week or month the loss occurred. If at the end of a quarter, losses exceed attrition figures, the Operations Group and Maintenance Group commanders will come to an agreement on how the shortfall will be corrected (United States Air Force 2008, 55).

Cancellation: A planned sortie that does not fly for any reason including maintenance, operations, supply, air traffic control, sympathy, higher headquarters, weather, and other uncategorized causes (United States Air Force 2008, 55).

Maintenance Cancel: A sortie that did not takeoff due to aircraft discrepancies, unscheduled maintenance, or for actions taken for maintenance consideration (United States Air Force 2008, 31).

Monthly Contract: The number of sorties required for the month, agreed upon by the Operations Group and Maintenance Group commanders (United States Air Force 2008, 18).

Monthly Schedule: The schedule, approved by the Operations and Maintenance Group commanders and signed by the Wing Commander, which represents the total number of sorties scheduled for the month. The monthly schedule includes the required sorties (contracted) and the attrition sorties.

Red Ball Maintenance: The maintenance performed on an aircraft to fix a malfunction reported while attempting to launch.

Spare Aircraft: An aircraft specifically designated on the flying schedule to replace aircraft that cannot fly its sortie (United States Air Force 2008, 59).

Utilization Rate: The rate representing the number of sorties per aircraft per month (United States Air Force 2006, 59).

APPENDIX A

DATA

MOB	Month	Required	Scheduled	Sch Att	Flown	Adds	Diff	y/n	rank	Att cat
DY	Jan-07	171	192	10.94%	178	4	3	yes	34	Low
LA	Jan-07	169	193	12.44%	182	3	10	yes	55	High
EL	Jan-07	80	93	13.98%	94	11	3	yes	71	High
MT	Jan-07	43	52	17.31%	58	0	15	yes	94	High
MT	Feb-07	62	70	11.43%	14	5	-53	no	43	Low
DY	Feb-07	169	195	13.33%	168	3	-4	no	66	High
LA	Feb-07	156	182	14.29%	139	0	-17	no	74	High
EL	Feb-07	49	58	15.52%	73	23	1	yes	83	High
MT	Mar-07	70	77	9.09%	68	0	-2	no	20	Low
LA	Mar-07	131	151	13.25%	131	0	0	yes	64	High
EL	Mar-07	90	106	15.09%	71	9	-28	no	81	High
DY	Mar-07	100	119	15.97%	113	1	12	yes	87	High
MT	Apr-07	68	72	5.56%	61	0	-7	no	12	Low
EL	Apr-07	99	112	11.61%	83	6	-22	no	48	Low
DY	Apr-07	192	218	11.93%	185	1	-8	no	51	Low
LA	Apr-07	125	142	11.97%	114	1	-12	no	52	High
MT	May-07	74	78	5.13%	51	0	-23	no	9	Low
LA	May-07	151	168	10.12%	147	0	-4	no	26	Low
EL	May-07	99	113	12.39%	85	7	-21	no	54	High
DY	May-07	200	230	13.04%	210	1	9	yes	62	High
MT	Jun-07	69	73	5.48%	63	3	-9	no	11	Low
EL	Jun-07	112	127	11.81%	82	10	-40	no	50	Low
DY	Jun-07	190	217	12.44%	199	0	9	yes	57	High
LA	Jun-07	131	151	13.25%	134	0	3	yes	64	High
MT	Jul-07	58	63	7.94%	61	3	0	yes	16	Low
EL	Jul-07	88	99	11.11%	64	4	-28	no	35	Low
DY	Jul-07	159	184	13.59%	169	7	3	yes	70	High
LA	Jul-07	166	193	13.99%	154	0	-12	no	72	High
MT	Aug-07	72	76	5.26%	58	0	-14	no	10	Low
EL	Aug-07	127	143	11.19%	51	4	-80	no	39	Low
LA	Aug-07	161	182	11.54%	157	5	-9	no	46	Low
DY	Aug-07	142	168	15.48%	156	4	10	yes	82	High
MT	Sep-07	65	68	4.41%	49	0	-16	no	7	Low
EL	Sep-07	160	180	11.12%	75	5	-90	no	38	Low
LA	Sep-07	118	133	11.28%	87	0	-31	no	41	Low
DY	Sep-07	101	120	15.83%	111	2	8	yes	86	High

Source: Created by the author with data provided by the MOS at Dyess AFB, Ellsworth AFB, Minot AFB, Barksdale AFB and Whiteman AFB.

MOB	Month	Required	Scheduled	Sch Att	Flown	Adds	Diff	y/n	rank	Att cat
MT	Oct-07	68	68	0.00%	68	2	-2	no	1	Low
EL	Oct-07	203	225	9.78%	219	9	7	yes	14	Low
LA	Oct-07	145	167	13.17%	138	0	-7	no	40	High
DY	Oct-07	122	143	14.69%	138	2	14	yes	47	High
WM	Oct-07	72	86	16.28%	104		32	yes	54	High
MT	Nov-07	55	56	1.79%	55	0	0	yes	5	Low
DY	Nov-07	91	101	9.90%	99	7	1	yes	17	Low
EL	Nov-07	160	178	10.11%	125	9	-44	no	18	Low
LA	Nov-07	164	188	12.77%	170	0	6	yes	39	High
WM	Nov-07	62	84	26.19%	102	1	39	yes	64	High
MT	Dec-07	46	51	9.80%	46	1	-1	no	15	Low
EL	Dec-07	132	147	10.20%	100	10	-42	no	19	Low
LA	Dec-07	135	153	11.76%	122	2	-15	no	33	Low
DY	Dec-07	102	122	16.39%	112	2	8	yes	56	High
WM	Dec-07	58	79	26.58%	84	5	21	yes	66	High
LA	Jan-08	169	193	12.44%	166	2	-5	no	35	High
DY	Jan-08	150	175	14.29%	160	2	8	yes	45	High
EL	Jan-08	92	110	16.36%	94	14	-12	no	55	High
MT	Jan-08	47	58	18.97%	48	0	1	yes	60	High
WM	Jan-08	75	102	26.47%	125		50	yes	65	High
MT	Feb-08	56	60	6.67%	57	0	1	yes	9	Low
DY	Feb-08	142	164	13.41%	150	2	6	yes	42	High
EL	Feb-08	81	95	14.74%	73	15	-23	no	48	High
LA	Feb-08	123	148	16.89%	157	0	34	yes	58	High
WM	Feb-08	57	73	21.92%	67	2	8	yes	63	High
MT	Mar-08	63	64	1.56%	62	2	-3	no	4	Low
DY	Mar-08	200	224	10.71%	196	2	-6	no	24	Low
LA	Mar-08	139	157	11.46%	134	0	-5	no	30	Low
EL	Mar-08	83	96	13.54%	71	6	-18	no	43	High
EL	Apr-08	97	105	7.62%	83	22	-36	no	10	Low
MT	Apr-08	72	79	8.86%	79	1	6	yes	12	Low
DY	Apr-08	185	207	10.63%	191	9	-3	no	23	Low
LA	Apr-08	128	144	11.11%	126	0	-2	no	26	Low
WM	Apr-08	65	75	13.33%	76	1	10	yes	41	High
DY	May-08	194	202	3.96%	173	4	-25	no	6	Low
EL	May-08	94	106	11.32%	85	11	-20	no	29	Low

Source: Created by the author with data provided by the MOS at Dyess AFB, Ellsworth AFB, Minot AFB, Barksdale AFB and Whiteman AFB.

MOB	Month	Required	Scheduled	Sch Att	Flown	Adds	Diff	y/n	rank	Att cat
LA	May-08	115	130	11.54%	104	0	-11	no	15	Low
MT	May-08	40	47	14.89%	43	0	3	yes	22	High
WM	May-08	135	161	16.15%	129	3	-9	no	26	High
MT	Jun-08	65	65	0.00%	64	1	-2	no	1	Low
DY	Jun-08	193	215	10.23%	187	12	-18	no	8	Low
EL	Jun-08	95	106	10.38%	82	16	-29	no	9	Low
LA	Jun-08	96	110	12.73%	99	1	2	yes	19	High
WM	Jun-08	134	159	15.72%	100	2	-36	no	24	High
EL	Jul-08	69	77	10.39%	64	15	-20	no	10	Low
DY	Jul-08	190	213	10.80%	182	2	-10	no	11	Low
LA	Jul-08	70	80	12.50%	64	2	-8	no	17	High
WM	Jul-08	97	113	14.16%	80	2	-19	no	20	High
MT	Jul-08	58	72	19.44%	58	0	0	yes	29	High
DY	Aug-08	180	180	0.00%	137	3	-46	no	1	Low
LA	Aug-08	109	119	8.40%	101	3	-11	no	5	Low
WM	Aug-08	105	120	12.50%	90		-15	no	17	High
EL	Aug-08	45	55	18.18%	51	9	-3	no	28	High
LA	Sep-08	112	118	5.08%	101	16	-27	no	3	Low
MT	Sep-08	50	53	5.66%	43	1	-8	no	4	Low
EL	Sep-08	77	87	11.49%	75	7	-9	no	14	Low
DY	Sep-08	155	186	16.67%	133	1	-23	no	27	High
EL	Oct-08	123	135	8.89%	101	4	-26	no	6	Low
LA	Oct-08	101	112	9.82%	70	0	-31	no	7	Low
DY	Oct-08	139	165	15.76%	140	2	-1	no	25	High
LA	Nov-08	120	135	11.11%	130	3	7	yes	12	Low
EL	Nov-08	79	89	11.24%	59	6	-26	no	13	Low
DY	Nov-08	114	133	14.29%	118	4	0	yes	21	High
LA	Dec-08	123	140	12.14%	118	1	-6	no	16	High
DY	Dec-08	131	154	14.94%	131	2	-2	no	23	High
EL	Dec-08	79	99	20.20%	60	13	-32	no	30	High

Source: Created by the author with data provided by the MOS at Dyess AFB, Ellsworth AFB, Minot AFB, Barksdale AFB and Whiteman AFB.

APPENDIX B

COMMONLY REFERENCED EQUATIONS

$$A = 1 - \frac{\sum S_f}{\sum S_{sch}} \tag{2.1}$$

$$\text{Min } Lex\ P1{:}h(\beta^+, \beta^-) \quad P2{:} \min g(\mathrm{a}^+, \mathrm{a}^-) \quad P3{:}\ \hat{f}(x) \tag{2.8}$$
$$\begin{aligned} \text{subject to } & x + \beta^+ - \beta^- \in \hat{X} \\ & x + a^+ - a^- = x^o \\ & a^+, a^-, \beta^+, \beta^- \geq 0 \end{aligned}$$

$$\chi^2 = \sum_{r=1}^{R} \sum_{c=1}^{C} \frac{n_{\bullet c}}{100} \frac{(P_{rc} - 100\hat{\pi}_{r\bullet})^2}{100\hat{\pi}_{r\bullet}} \tag{3.3}$$

$$F_{rc} = \frac{n_{r\bullet} \times n_{\bullet c}}{n_{\bullet\bullet}} \tag{3.4}$$

REFERENCE LIST

Barnhart, Cynthia, and Amy Cohn. "Airline schedule planning: Accomplishments and opportunities." *Manufacturing & Service Operations Management*, January 1, 2004: 3-22.

Brandt, David. "Stricken with lean." *Indistrial Engineer*, March 1, 2008: 52-53.

Chase, Richard B., Nicholas J. Aquilano, and F. Robert Jacobs. *Operations management for competitive advantage.* 9th. New York: McGraw-Hill, 2001.

Correll, John T. "Strung out." *Air Force Magazine,* September 1, 1998: 4.

Edwards, Allen L. *Statistical methods.* 3rd. New York: Holt, Rinehart and Winston, Inc., 1973.

Gay, L. R. *Educational research: Competencies for analysis and applications.* 5th. New Jersey: Prentice-Hall, Inc., 1996.

George, David, Kristen F. Lynch, Robert S. Tripp, and John G. Drew. "A historical perspective: Maintenace organization." *Air Force Journal of Logistics*, January 1, 2004: 28-38.

Glass, Gene V., and Kenneth D. Hopkins. *Statistical methods in education and psychology.* 3rd. Boston: Allyn & Bacon, 1996.

Gonzalez, V., L. F. Alarcon, and F. Mundaca. "Investigating the relationship between planning reliability and project performance." *Production Planning & Control*, July 1, 2008: 461.

Hoel, Paul G., and Raymond J. Jessen. *Basic statistics for business and economics.* 2nd. New York: John Wiley & Sons, 1982.

Howe, Jeremy A., Benjamin A. Thoele, A. Scotty Pendley, Anthony F. Antoline, and Roger D. Golden. "Beyond authorized versus assigned." *Air Force Journal of Logistics*, January 1, 2007: 14-24.

Kohl, Larson N., A. Ross, and S. Tiourline. "Airline disruption management." *Technical report CRTR-0407.* Atlanta: Carmen Research, 2004.

Lowry, Richard. *VassarStats: Web site for statistical computation.* http://faculty.vassar.edu/lowry/tab2x2.html (accessed March 20, 2009).

Mendenhall, William. *Introduction to probability and statistics.* 5th. Belmont: Wadsworth, 1979.

United States Air Force. Air Combat Command instruction 21-165, *CAF: Aircraft flying and maintenance scheduling procedures.* Washington, D.C.: U.S. Government Printing Office, 2008.

———. Air Combat Command supplement to Air Force instruction 11-102, *Flying hour program management.* Washington D.C.: U.S. Government Printing Office, 2007.

———. Air Force doctrine document 1, *Basic doctrine.* Washington D.C.: U.S. Government Printing Office, 2003.

———. Air Force doctrine document 2-4, *Combat support.* Washington D.C.: U.S. Government Printing Office, 2005.

———. Air Force instruction 11-102, *Flying hour program management.* Washington D.C.: U.S. Government Printing Office, 2002.

———. Air Force intstruction 21-101, *Aircraft and equipment maintenance management.* Washington D.C.: U.S. Government Printing Office, 2006.

———. Air Force tactics, techniques and procedures 3-21, *Aircraft maintence.* Washington D.C.: U.S. Government Printing Office, 2007.

Westmeyer, Paul. *A Guide for use in planning, conducting, and reporting research projects.* 5th. Springfield: Thomas, 1994.

Womack, James P., and Daniel T. Jones. *Lean thinking: Banish waste and create wealth in your corporation.* New York: Free Press, 2003.

Yao, Yufeng, Wei Zhao, Ozlem Ergum, and Ellis Johnson. “Aircraft scheduling with maintenance and crew considerations.” *American Institute of Aerodynamics and Astronautics*, 2005.

Yu, Gang, and Xiangtong Qi. *Disruption management.* New York: World Scientific Publishing Company, Inc., 2004.

INITIAL DISTRIBUTION LIST

Combined Arms Research Library
U.S. Army Command and General Staff College
250 Gibbon Ave.
Fort Leavenworth, KS 66027-2314

Defense Technical Information Center/OCA
825 John J. Kingman Rd., Suite 944
Fort Belvoir, VA 22060-6218

Mr. Lowell E. Solien
DLRO
USACGSC
100 Stimson Avenue
Fort Leavenworth, KS 66027

Dr. Thomas G. Clark
CTAC
USACGSC
100 Stimson Avenue
Fort Leavenworth, KS 66027

Lt Col David M. Stephan
DJMO
USACGSC
100 Stimson Avenue
Fort Leavenworth, KS 66027